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PHYSICAL WORK CAPACITY ALONG WITH MUSCULAR STRENGTH AND ENDURANCE LEVELS OF INTERCOLLEGIATE HOCKEY PLAYERS

by

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A THESES

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Abstract

Thirty intercollegiate hockey players at the University of Alberta were tested three times during the 1973 - 1974 ice hockey season to determine changes in fitness during the season. Preseason, midseason and postseason values were determined for physical working capacity, maximal O_2 intake and muscular strength and endurance parameters. Sixteen undergraduate students enrolled in service programs of the Department of Physical Education acted as control subjects. Physical working capacity and maximal O_2 intake of the hockey players increased significantly between preseason and midseason, and showed no further increase for the remainder of the season. No significant increase was observed in muscular strength and endurance of the hockey players between preseason and midseason testing. An in-season weight training program produced significant increase in the muscular strength and endurance of hockey players. Playing performance of the hockey players correlated significantly with body weight for the varsity players studied. Physical working capacity, maximal O_2 intake, arm strength and strength index did not correlate significantly with playing performance. It was concluded that a season of intercollegiate ice hockey increased the physical working capacity and maximal O_2 intake but did not significantly improve muscular strength and endurance. An in-season weight training program did increase the strength and endurance levels of ice hockey players.

Dedication

To Cheryl, with love and appreciation
for the encouragement, support and
loving homelife provided during our
two years in Edmonton.

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CHAPTER I

INTRODUCTION

Introduction

A number of studies have been conducted concerning the effects of conditioning methods upon various physiological parameters (Freeman et al, 1955; Brown, 1960; Cureton, 1957; MacKenzie, 1935; Robinson and Harmon, 1941; Astrand et al, 1960). Few studies (Watson, 1965; Selder, 1964; Chambers, 1967; Green et al, 1972a; Green 1973; Ferguson et al, 1961; and Howell, 1966) have dealt with the training effects of ice hockey programs upon these physiological parameters. At present these studies form the basis of scientific knowledge concerning the physiological response to a competitive season of ice hockey.

Howell(1966) and Ferguson et al (1969) were concerned with the determination of maximal oxygen intake of collegiate hockey players and found values of 57 and 55 ml/kg/min, respectively, for this parameter. Watson (1965) studied maximal oxygen intake as well and found that a season of ice hockey significantly increased the maximal oxygen consumption of ten University of Alberta varsity hockey players from 3.51 to 4.11 l/min or 45.22 to 54.26 ml/kg/min. Green (1972) described a change in maximal oxygen intake from 4.02 to 4.18 l/min or 53.9 to 56.4 ml/kg/min during a season of intercollegiate hockey. These results are consistent with seasonal changes reported by Howell (1966). Green (1973) reported that virtually no seasonal change in maximal oxygen consumption occurred for both university and junior hockey players studied.

For the most part, the studies mentioned above concentrated mainly upon maximal oxygen intake as a measure of fitness, although Green et al (1972b) did examine anaerobic capacity as well. The present study was initiated to determine what changes in aerobic capacity, as indicated by PWC_{170} and predicted Max $\dot{V}O_2$ occurred during a season of intercollegiate ice hockey. Seasonal changes in muscular strength and endurance, and the effectiveness of an in season weight training program were also examined. Since strong emphasis has not been previously placed on the investigation of muscular strength and endurance levels of intercollegiate hockey players, it is hoped that the values measured in the present study are valuable in the establishment of norms for muscular strength and endurance of intercollegiate hockey players. It is also hoped that the assessment of the in season weight training program will establish that such a program is a valuable contribution to the overall fitness of intercollegiate hockey players.

Statement of the Problem

The main purpose of this study was to determine what changes occurred in the fitness levels of intercollegiate hockey players during a competitive season. The fitness parameters examined were:

1. physical work capacity as measured by the Sjostrand PWC_{170} test
2. maximal oxygen intake predicted from the Astrand - Rhyming nomogram
3. muscular strength and endurance as measured by the Grip Strength, Chin-ups, Shoulder-dips, Arm Strength Index, Back Strength, Leg Strength, and Strength Index

Two subsidiary problems were also investigated in the study:

1. the effectiveness of an in season weight training program upon muscular strength and endurance levels
2. correlations between the fitness levels of the players and their performance during the season

Rationale Behind the Study

Scientific investigation of fitness levels and training procedures of Canadian ice hockey players has been limited. Following the first Canada - Russia hockey series in 1972, many hockey and fitness experts advocated the implementation of more scientific training and coaching methods for hockey programs at all age levels.

Scientific knowledge has been applied to ice hockey in two ways:

1. to teach the proper execution of the basic skills of the game, i.e., skating, passing, shooting, and checking
2. to develop optimum fitness levels through proper conditioning exercises

Green et al (1972b) and Green (1973) have advocated the types of scientific training stimuli that are necessary during on-ice sessions to develop maximal fitness levels for competitive hockey. The present study examined the training effects of such an on-ice training program, used at the University of Alberta, to see if maximal fitness levels were attained.

Weight training programs have been advocated and used by hockey players for a number of years to supplement on-ice training. Bukac (1968) noted that top level Russian hockey teams started preseason training in July for the coming competitive season. An integral part of this preseason conditioning program was a weight training program to develop a high level of muscular strength and endurance before the competitive season. This high level of strength was maintained during the hockey season by one weight lifting session per week.

In Canada, strict weight training programs are not often performed by hockey players during the off season, but weight training programs have sometimes been conducted during the season. The present study examined the effect of such an in season weight training program on levels of muscular strength and development.

Limitations and Delimitations of the Study

1. The study was restricted to 30 male intercollegiate hockey players at the University of Alberta, and 18 male university undergraduate students who acted as control subjects.
2. Physical working capacity was determined by the Sjostrand PWC_{170} test.
3. Maximal oxygen intake was predicted using the Astrand - Rhyming Nomogram.
4. Muscular strength and endurance were measured using the Arm Strength and Strength Indices.
5. Subjects were tested three times; October, January and March, corresponding to preseason, midseason, and postseason values.
6. The control subjects were free to exercise at will, individuals who played hockey during the season were not selected as subjects.
7. Temperature, barometric pressure and humidity were not controlled during testing.
8. Subjects were asked not to participate in physical exercise before testing, but no external controls were used to enforce this request.
9. The time of day of testing was not strictly controlled.

Definition of Terms

Maximal oxygen intake (aerobic capacity) is defined in terms of the linear relationship between progressively increasing workloads and O_2 consumption; until VO_2 per unit time remains constant, falls or slightly increases, even though workload may increase.

Physical Work Capacity$_{170}$ (PWC_{170}) is defined as the intensity of work in kilopond meters per minute which the subject could perform at a pulse rate of 170 beats per minute.

Steady state heart rate is the heart rate between two successive readings taken at one minute intervals, which do not differ by more than ±5 beats.

Workload is the calibrated force of a friction belt which must be overcome by a subject while cycling at a prescribed rate. The work done is the product of the cycling rate, the distance cycled as determined by wheel circumference and revolutions, and the belt resistance.

Kilapondmeter (kpm) is the force developed by a kilogram mass under the influence of gravity for one meter.

Arm Strength Index is a muscular endurance index calculated from chin-ups and shoulder-dips, with height and weight factors included.

Strength Index is a fitness inventory obtained by summing values for left and right grip strength, back strength, leg strength, arm strength index and vital capacity.

CHAPTER II

REVIEW OF LITERATURE

Aerobic Capacity as a Measure of Fitness

The capacity of an individual to withstand prolonged, heavy work has been reported to be the most important component of fitness (Astrand, 1956; Balke, 1960; Hettinger et al, 1961). Rodahl and Issekutz (1962: 277) state that, "during heavy, prolonged physical work, the individual's performance capacity depends largely on his ability to take up, transport and deliver oxygen to the working muscle." Several other studies consider maximal oxygen intake or aerobic capacity to be the best measure of cardio-respiratory fitness (Astrand, 1956; Hettinger, et al, 1961; Newton, 1963; Rodahl et al, 1961; Taylor et al, 1963).

Astrand and Saltin (1961) suggested that the measurement of maximal oxygen uptake (aerobic capacity) of a subject when performing muscular exercise gives the maximal rate of energy output by combustion within the body. To further illustrate this point, Rodahl et al (1961) stated that

> the reloading of the contractile mechanism demands energy which in turn is liberated either from the restricted stored in the muscles themselves or from food storage from the blood stream. The rate of work that can be maintained over a longer period will, therefore, mainly depend on the transportation capacity of the cardio-respiratory system.

In order to test circulatory and respiratory fitness, work must be chosen that engages large muscle groups at a high intensity for

a duration which is long enough to allow circulatory and respiratory adjustments to the stress of the exercise (Astrand, 1952). Wahlund (1948) stated that tests in which a large number of muscles are required, maximum oxygen consumption should be regarded as a reliable measure of maximum work capacity. He described physical working capacity to be a continum, from the heart patient to the highly conditioned athlete. The capacity to maintain a high oxygen consumption over a period of time demonstrates a large degree of cardio-vascular and respiratory fitness (Taylor, 1958). Newton (1963) noted that the maximal rate at which oxygen can be consumed is an important measure of the ability of the circulatory and the respiratory systems to withstand the stress imposed by strenuous physical activity. Maximal oxygen intake is not only the best physiological indicator of the capacity of a man for sustaining hard work, it is also the most objective measure which indicated the physical fitness of an individual as reflected by his cardiovascular system (Newton, 1963).

Hettinger et al (1961) agreed that maximal oxygen intake is probably the best measure of a physical fitness, but pointed out a number of problems associated with its direct determination. Elaborate laboratory procedures, time required, the necessity of a maximal workload, and the difficulty of untrained subjects to reach VO_2 Max are some of these problems (Hettinger et al, 1961).

Prediction of Aerobic Capacity

As mentioned above, a number of problems are associated with the direct determination of maximal oxygen intake (Hettinger et al, 1961; Rowell et al, 1964; and Mitchell et al, 1958). Because of these

problems many submaximal tests have emerged which predict aerobic capacity from observations taken during submaximal work (Astrand, 1952; Balke, 1959; Cunningham, 1963; de Vries and Klafs, 1964; Issekutz, 1960; Sjostrand, 1947; Workman et al, 1964; Margarea et al, 1965; Shephard, 1966).

Such submaximal tests can be used to obtain an easy and reasonably accurate estimation of aerobic capacity. Under controlled conditions, the standard error of prediction of submaximal tests is 10 to 15% (Astrand and Rodahl, 1971). Taylor et al (1963) concluded that it is generally agreed that during submaximal work on a bicycle ergometer, O_2 consumption can be predicted with a reasonable degree of accuracy if the weight of the subject is known and the rate of work is known and maintained constant.

Astrand - Rhyming Nomogram

In 1954, Astrand and Rhyming introduced a nomogram for the prediction of maximal oxygen intake from a steady state heart rate at a known work load.

The nomogram was based on the heart response of eighty-six physical education students to exercise. Examination of the data showed that the average pulse rate (beats/min) for men and women at an oxygen intake representing 50% of the maximal O_2 intake was 128 and 138, respectively. At 70% of maximal O_2 intake, average heart rates of 154 (male) and 168 (female) were observed.

Using these results, Astrand and Rhyming constructed the nomogram on the assumption that the heart rate would approximate 128 (male) at 50% maximal O_2 intake and a maximal heart rate of 195 beats

per minute. Astrand (1960) outlined the prerequisites for using the nomogram:

1 . that the pulse rate increases approximately linearly with the oxygen intake during submaximal exercise.
2. that submaximal pulse rates not lower than 125 beats per minute be used.
3. that the subject can reach a maximal heart rate of 195 (±10) during maximal exercise.

Adjustments have been made to allow the nomogram to be applied to a wider range of people. Astrand (1960) introduced an age factor to deal with the decline in maximal heart rate with age. A further age correction factor was introduced in 1965 for subjects under fifteen years of age (Astrand, 1965).

Validity of the Astrand - Rhyming Nomogram

Astrand and Rhyming (1954) established the validity of their nomogram by comparing the predicted maximal O_2 values with the actual values. Analysis of the values revealed a mean difference of 0.023± 0.059 (males) and 0.010± 0.051 (females) litres of O_2 per minute between the predicted and actual values of maximal O_2 intake. Lower standard deviation values were reported for both men and women for a higher rate of work: 6.7% (male) and 9.4% (female) at a work load of 1200 and 900 KPM compared to 10.4% (male) and 14.4% (female) at work loads of 900 and 600 KPM. Astrand and Rhyming (1954) also reported a study using 18 well-trained male subjects, 18 - 19 years of age. A mean defference of 0.006± 0.066 l/min was reported between

actual and predicted values.

In 1960, Astrand reported the standard error of the nomogram method for predicting maximal O_2 intake to be about 10% for well-trained subjects and about 15% for moderately trained individuals.

Dobeln et al (1967) reported a standard deviation of 17% between predicted and actual maximal O_2 values for 84 persons between the ages of 30 and 80. Dobeln found that the nomogram underestimated the maximal O_2 intake by 0.15 liter/minute. Rowell et al (1964); Chase et al (1966) and Wyndham et al (1959) reported similar findings. Astrand and Rodahl (1971) stated that untrained persons are often underestimated, while extremely well-trained athletes are often overestimated. However, Glassford et al (1965) reported close agreement between actual and predicted values of maximal O_2 intake.

Hettinger et al (1961) reported a significant difference between predicted and actual maximal O_2 consumption (2.38 and 2.26 l/min) in 28 policemen 20 to 30 years of age. This difference was significant at the 5 per cent level of confidence. It was suggested that the subjects did not attain true maximal O_2 levels due possibly to their lack of training.

In a similar study, Rodahl et al (1961) tested 9 policemen between the ages of 23 and 48 years and found a difference of only 4.8% (2.65 to 2.54 l/min) between predicted and actual values. In another group of untrained men, 23 to 48 years of age, the difference was insignificant; with values of 2.72 and 2.76 l/min for predicted and actual maximal O_2 intake (Rodahl et al, 1961).

In 1964, deVries and Klafs used 16 physical education students, 20 to 26 years of age, to determine correlations and

predictive errors in predicting maximal O_2 consumption from submaximal tests of work capacity. An O_2 consumption value obtained from the Astrand - Rhyming nomogram correlated significantly ($r = 0.736$) with a value obtained from a maximal test on the bicycle ergometer.

Wyndham et al (1959) criticized the nomogram because they found that it underestimated the maximal oxygen intake by 0.32±0.14 l/min. They believed that the nomogram did not take into account that the pulse rate - oxygen consumption curve deviates towards O_2 consumption at high pulse rates.

Astrand (1960) however, stated that the nomogram was not based on the assumption that heart rate is a linear function of O_2 intake throughout the entire range of heart rate values. Astrand pointed out that since the study of Wyndham et al was conducted at an altitude of 5,500 feet, the observed difference between predicted and maximal O_2 values might be due to the effects of hypoxia.

Rowell et al (1964) demonstrated the influence of training on prediction with the nomogram. Using subjects 18 to 24 years old, they found the predicted test underestimated the maximal O_2 value by 11 ± 7 % after training compared to 27 ± 7 % before training. They also reported an underestimation of 5.6± 4% for a group of 10 highly trained endurance athletes.

Baycroft (1964) compared predicted values using the Astrand-Ryming nomogram with actual valued determined with the Mitchell et al test and the Astrand Bicycle test for 48 physically active males. He reported a significant correlation ($r = .62$) with the Astrand Bicycle test values.

Glassford (1964) used 24 physically active males to compare

the Astrand - Rhyming nomogram test with four maximal oxygen tests. Values in liters per minute obtained on the Astrand - Rhyming predicted test correlated well with the Johnson - Brouha - Darling test, ($r = .78$); the Mitchell - Sproule - Chapman test, ($r = .80$); the Taylor - Buskirk - Henschel test, ($r = .72$); and the Astrand test, ($r = .65$). The correlation between the nomogram values and any one set of directly measured values was as good as the correlation between the values of any two direct techniques examined in the study.

Hyde (1965) investigated the validity of the nomogram for secondary school children. He reported predicted values equivalent to those obtained on the Astrand actual test for the 27 females studied. However, the predicted values for the 28 males were underestimated by 9.74%, a significant difference at the 1 per cent level of confidence.

History of Sjostrand P W C $_{170}$ Test

The first reported use of the Sjostrand test was in 1947, Sjostrand reported findings on the physical work capacity of 20 ore smelting workers. The test utilized workloads of 300, 600, 900, and occasionally 1200 kpm/min for a ten minute interval at each workload, except the last, which was either four or six minutes.

Wahlund (1948) tested 469 adult males on a bicycle ergometer starting at a workload of 300 or 600 kpm/min and increasing the work load every 6½ minutes by 300 kpm/min until the subject was exhausted or work at 1200 kpm was done. Pulse rates were determined at 2 minute intervals throughout the test.

Kjelberg et al (1950) made a further modification of the Sjostrand test by shortening the times of each workload to 6 minutes and extrapolating the pulse curve to 170 beats per minute. Other testing procedures were as outlined by Wahlund.

Bengtsson (1956) refined the Sjostrand test further in 1956. He applied the concept of steady state heart rate to the test. Workloads were adjusted so that heart rates would be approximately 125 - 130, 140 - 150, and about 170 beats per minute for successive workloads.

In 1961 Adams et al used the Sjostrand test to study 243 normal school children in California. They attempted to adjust workloads for each subject so that heart rates of 100 - 120, 120 - 140, and 150 - 170 were attained in successive work periods.

In another study Adams et al (1961) made a modification to the Sjostrand test by using only 2 successive workloads instead of 3 and trying to obtain heart rates about 140 on the first test and approximately 170 on the second.

Cummings and Cummings (1963) employed the Sjostrand test procedure of Adams (1961b). Cummings and Danzinger (1963) followed the procedure of Adams (1961a) to administer the Sjostrand test.

de Vries and Klafs (1964) also used only two consecutive workloads; however, they used predetermined loads of 450 and 900 kpm/min.

Zahar (1965) used 38 high school students to study the reliability of the test with repeated measures. He used three consecutive six minute work periods, each at a higher work load.

Fedoruk (1969) also studied the reliability and validity of the Sjostrand PWC_{170} test. However, he employed a 12 minute contin-

uous bicycle ride consisting of 3 four minute work periods at successively higher work loads.

Validity and Reliability of Sjostrand P W C $_{170}$ Test

Borg and Dahlstrom (1962) reported re-test correlations for the P W C $_{170}$ of r = .76, compared to a value of .71 on the Astrand - Rhyming Nomogram test.

They also reported an intra-test correlation of .97 for the P W C $_{170}$ test. Borg and Dahlstrom checked the validity of the P W C $_{170}$ test as well. Using the results of a ski race as the criterion, they found correlations of r = .46 and r = .54 between the criterion test and the first and second P W C $_{170}$ tests.

Borg and Dahlstrom reported another study done by Linderholm that reported on the reliability of the P W C $_{170}$ test. Linderholm found a test - retest correlation between two tests 4 days apart of .97 for a group of 18 men and women with a P W C $_{170}$ ranging from 625 - 1555 kpm/min.

Fedoruk (1969) reported test - retest correlations of .91 and .75 for males and females when the P W C was expressed in kpm/min. These coefficients reduced to .87 and .70 when expressed in kpm/kg/min. A comparative re-test reliability of .88 (males) and .83 (females) was obtained on the Mitchell - Sproule - Chapman test. Comparison between the correlation coefficients of the mean of two Sjostrand trials with the criterion maximum test and two maximum trials revealed a nonsignificant difference for the male subjects studied. This led Fedoruk to conclude that with the possible exception of the Sjostrand P W C$_{170}$

test, no submaximal test studied was as valid a predictor of physical fitness as was another maximum O_2 intake test.

In 1964, de Vries and Klafs conducted a study to investigate the validity of several submaximal work capacity tests by comparing the predicted values with an actual maximal oxygen consumption value determined on a bicycle ergometer. Of the submaximal tests used the Sjostrand P W C $_{170}$ correlated best with the test criterion .877. This correlation was significant at the 5 per cent level of confidence.

Zahar (1965) investigated the reliability of the Sjostrand P W C $_{170}$ test with repeated trials. He reported an initial re-test correlation of .886 with the 38 male high school students studied. The succeeding test - retest reliabilities were: .894, .841, .877, and .947. Zahar concluded that the Sjostrand P W C $_{170}$ test was a highly reliable measure of physical work capacity for the group studied.

Miki (1969) reported that physical working capacity (P W C $_{170}$ kpm/min) was significantly related to oxygen intake in l/min in zero order and first order correlation analysis ($p = .01$). He found that O_2 intake in ml/kg/min was the best predictor of P W C $_{170}$ expressed as kpm/kg/min.

Holmgren et al (1967) reported correlation coefficient of .903 between the Sjostrand test and O_2 intake values.

Work Capacity Studies Using the P W C $_{170}$ Test

Adams et al (1961a) used 120 boys and 123 girls between the ages of 6 and 14 years. They found that working capacity increased

with age, height, weight, and body surface area. The best correlations were with the logarithm of the surface area, .81 for males and .80 for females; and with logarithm of the weight, .81 for males and .77 for females.

Adams et al (1961b) conducted a study with 196 country and urban school children aged 10 to 12 years. They found that:

1. P W C was significantly greater with increasing degree of training for boys and girls in both city and country environment.
2. P W C was found to increase with age, height, weight, surface area, heart volume and degree of physical fitness.
3. a significant difference in P W C between city and country girls (p = .02), but no significant difference between rural and urban boys in P W C.
4. a significant difference (p = .01) for Swedish and California girls in P W C.
5. P W C of California boys compared favourably with Swedish boys.

Cummings and Cummings (1963) conducted a work capacity study on 200 Winnipeg school childran, They found that:

1. a high correlation existed between P W C of boys and their height, .865, weight, .897 and body surface area, .904.
2. the P W C of 11 and 12 year old Winnipeg boys and girls tended to be smaller than those of similar aged children

in California and Sweden.

Fedoruk (1969) reported a mean P W C $_{170}$ for 24 first year physical education students to be 1345 kpm/min. A CAPHER study reported norms of 873.8 ± 224.5 kpm/min for 17 year old high school males across Canada. Zahar (1965) reported the P W C $_{170}$ of 38 high school males to be 943, 973, 994, 1039, 1018, and 1003 kpm/min on six repeated trials.

Fitness Levels of Intercollegiate Hockey Players

As noted in the introduction, not much research has been carried out into the fitness levels of intercollegiate hockey players. Most of the early studies dealt exclusively in aerobic capacity (Howell et al, (1966); Ferguson et al, (1969); and Watson, (1965).

Watson (1965) studied 10 University of Alberta varsity hockey players to determine the seasonal changes in maximal O_2 intake as measured by the modified Mitchell - Sproule - Chapman maximal oxygen consumption test. He found that a season of ice hockey significantly increased the maximal O_2 intake of the hockey players over that of a control group when expressed in terms of liters/min. There was no significant difference in maximal O_2 intake between the two groups when expressed in ml/kg/min. The hockey players showed a 17.46% increase in O_2 intake during the season, going from 3.51 l/min to 4.11 l/min; compared to an 8.65% increase for the control group, who went from 3.38 l/min to 3.67 l/min. The hockey group increased from 45.22 to 54.26 ml/kg/min, when O_2 intake was expressed in terms of

body weight.

Howell et al (1966) reported maximal oxygen consumption of intercollegiate hockey players of 57 ml/kg/min. Ferguson et al (1969) observed similar results of 57 ml/kg/min for intercollegiate hockey players.

In recent work at the University of Waterloo, Green and co-workers (1972b) have recognized the need to examine more than just aerobic capacity in assessing the fitness of competitive ice hockey players. Green et al (1972b) have conducted investigations to determine the nature and magnitude of any adaptive changes that occurred in body composition, aerobic capacity, anaerobic capacity, and a number of respiratory functions of ice hockey players during a competitive season. They found increases in aerobic capacity during the season (from 4.02 liters per minute to 4.18 liters per minute; or from 53.9 to 56.4 when expressed in milliliters of O_2 per kilogram of body weight per minute) to be nonsignificant. Defencemen underwent the greatest seasonal change, improving from 50.7 to 55.2 ml/kg/min, but nonetheless remained below the post season value of forwards (58.1 ml/kg/min).

In the same study, it was also reported that a 17% increase in anaerobic capacity, as measured by peak lactate values and running time on a short exhaustive treadmill run occurred during the season.

Green (1973) reported the aerobic capacity of both junior and intercollegiate hockey players to be approximately 55 ml/kg/min. In discussing seasonal changes, Green observed that virtually no change in aerobic capacity occurred (from 4.30 to 4.43 liters per minute, or 56.4 to 57.1 ml/kg/min). He did, however, find a 15% increase in anaerobic capacity over the course of the season.

A study conducted on a junior hockey team in Canada during the 1973-74 season showed the effects of a supplementary conditioning program (Neilson, 1974). The team participated in a jogging and weight training program to supplement its on-ice practices. Results showed a higher aerobic capacity (62.2 ml/kg/min) than reported elsewhere in the literature for hockey teams.

Also investigated in the above study were muscular strength measures. Grip strength values tended to remain constant, with post-season values reported of 124 pounds for left grip strength and 137 pounds for the right grip strength. Definite improvements during the season in back and leg strength were noted, however. Post season values of 426 pounds (back strength) and 1018 pounds (leg strength) were reported.

CHAPTER III

METHODS AND PROCEDURE

Thirty intercollegiate hockey players and sixteen male undergraduate students at the University of Alberta during the 1973-74 year were used in the study. The sixteen control subjects were students enrolled in physical activity service courses offered by the Department of Physical Education.

All subjects were tested three times during the course of the hockey season: the preseason test was done during training camp before the season began. Midseason testing was conducted in January, and the postseason testing was carried out in March, at the completion of the season.

During each testing session, the subjects' height and weight were recorded. The subject was then tested on the following test items: vital capacity, right and left grip strength, back strength, leg strength, shoulder dips, chin-ups, and P W C $_{170}$. Arm strength and strength index were calculated from the raw data. The P W C $_{170}$ values were calculated with an Olivetti program. Maximal O_2 intake values were predicted using the Astrand - Rhyming Nomogram.

All hockey players were given the opportunity to participate in the in-season weight training program. The program was based on the 10 RM principle with players performing two sets of ten repetitions two days a week. The program was maintained for seven weeks during the second half of the season, between the second and third test trials. Some players could not participate in the program due to academic or

extracurricular commitments. Fifteen players participated in the weight training program, while the other fifteen did not.

The subjects were divided into three groups for the purpose of data analysis. The sixteen non-hockey players from the activity classes acted as control subjects. The fifteen hockey players who did not weight train were classified as the first treatment group, while the fifteen hockey players who did weight train comprised a second treatment group.

Changes in aerobic capacity and physical working capacity were anticipated for the two hockey groups. The effect of the in-season weight training program on the muscular strength and endurance of the hockey players was examined. The activity levels of the control subjects were not limited, therefore small changes in some parameters studied may have occurred due to the physical activity that they pursued.

Muscular Strength and Endurance

Testing procedures for grip strength, back strength, leg strength, shoulder-dips, chin-ups, vital capacity, arm strength index and strength index were conducted as described by Clarke (1967).

Modified Sjostrand P W C $_{170}$ Test

The Sjostrand P W C $_{170}$ test is based on the principle of a linear relationship that exists between steady state pulse frequencies and the work load producing these pulse frequencies (Astrand, 1965).

The value of the P W C $_{170}$ is usually found by extrapolation after plotting the work load and heart rates obtained during the test. In this study this extrapolation was done by an Olivetti 101 program.

The subjects were required to complete a twelve minute continuous exercise bout consisting of three four minute work periods at successively higher workloads. The cycle rate of 60 rpm was used.

Subjects started at work loads ranging from 360 - 720 kpm. The second and third work loads were adjusted according to the steady state heart rate during the third and seventh minutes of cycling. Adjustment of the workload was aimed at attaining three steady state heart rates within the ranges of 110 - 125, 135 - 145, 155 - 165 bpm at the fourth, eighth, and twelth minutes of cycling.

Pedal revolutions were counted and recorded at the end of each four minute period to enable accurate determination of work performed in each period.

The heart rates were plotted against workloads and the workload necessary to produce a heart rate of 170 bpm was determined to be the P W C $_{170}$. The subject's score was the work in kilapond meters that would produce a steady heart rate of 170 beats per minute.

Prediction of Maximal O_2 Intake

Maximum O_2 intake was predicted using the Astrand - Rhyming nomogram (Astrand and Rhyming, 1954). The nomogram like the Sjostrand test is based on linear relationships existing among heart rate, oxygen consumption, and workload throughout the range of heart rate values to

approximately 195 ± 10 bpm.

Statistical Analysis

The data was analyzed using a two factor ANOVA with repeated measures on one factor (Winer, 1972). The Newman - Keuls Test was used to examine the difference between mean scores (Kirk, 1969). Differences at the .05 level of confidence were considered to be significant. Data analysis was conducted on the University of Alberta 3600 computer system.

Fitness and Performance

A paired preference test was given to the hockey players to determine which players were the best performers during the season. The test asked the question, "for each of the pairs listed below choose the player you felt made a more valuable contribution to the performance of the team during the season."

Scores obtained from the test were correlated with the post season values for PWC_{170}, maximum O_2 intake, arm strength index, strength index and body weight to illustrate any relationship that may have existed between fitness levels and performance.

The hockey players were split into two groups, juniors and seniors for the purpose of making the fitness-performance comparison.

CHAPTER IV

RESULTS

Within Subject Differences (Time Effect)

The analysis of variance* revealed significant differences in P W C $_{170}$, MVO_2 (liters/min), MVO_2 (ml/kg/min), arm strength, strength index, back strength, right grip strength, chin-ups, shoulder-dips and vital capacity (Tables 6, 7, 8, 9, 10, 11, 14, 15, 16, 17) within subjects over the three trials at the .01 level of significance. Leg strength and left grip strength (Table 12 and 13) also changed significantly ($p = .05$).

P W C $_{170}$, MVO_2 (liters/min) and MVO_2 (ml/kg/min) varied similarily over the three trials. The Newman - Keuls** test of significance showed a significant change ($p = .01$) between trials 1 and 2 and trials 1 and 3, but no significant difference between trials 2 and 3 (Tables 18 to 20).

Arm strength and back strength were the only parameters studied that increased significantly between trials 2 and 3 ($p = .05$) and between trials 1 and 3 ($p = .01$), while shoulder dips (Table 28) increased significantly between trials 1 and 2 ($p = .05$) and between trials 1 and 3 ($p = .01$).

Strength indes (Table 22) showed a significant change between trials 1 and 3 only ($p = .05$).

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* ANOVA tables are found in Appendix A

** Newman - Keuls tests of significance are found in Appendix B

Leg strength, left end right grip strength and vital capacity (Tables 24, 25, 26, 29) revealed no significant difference between trials.

Between Subjects Differences (Group Effect)

The analysis of variance (Tables 6 to 8) indicated a significant difference existed among the three treatment groups at the .01 level of significance for PWC_{170}, MVO_2 (liters/min), and MVO_2 (ml/kg/min). However, examination of mean differences failed to reveal any differences except between the control and hockey groups in MVO_2 when expressed in ml/kg/min ($p = .05$) (Tables 30 to 32).

No significant differences were found between groups for any of the other variables studied (arm strength, strength index, back strength, leg strength, grip strength, chin-ups, shoulder-dips, or vital capacity) (Tables 33 to 41).

Group Times Time Differences (Interaction Effect)

Data analysis disclosed that significant interaction effect (group . time) existed at the .01 level of confidence for arm strength, strength index, chin-ups, and shoulder dips (Tables 9, 10, 15, 16). PWC_{170}, MVO_2 (liters/min), MVO_2 (ml/kg/min), and leg strength showed an interaction effect at the .05 level of confidence (Tables 42, 43, 44 and 48).

The remaining variables studied (back strength, grip strength and vital capacity) did not undergo an interaction effect.

FIGURE I

PHYSICAL WORKING CAPACITY

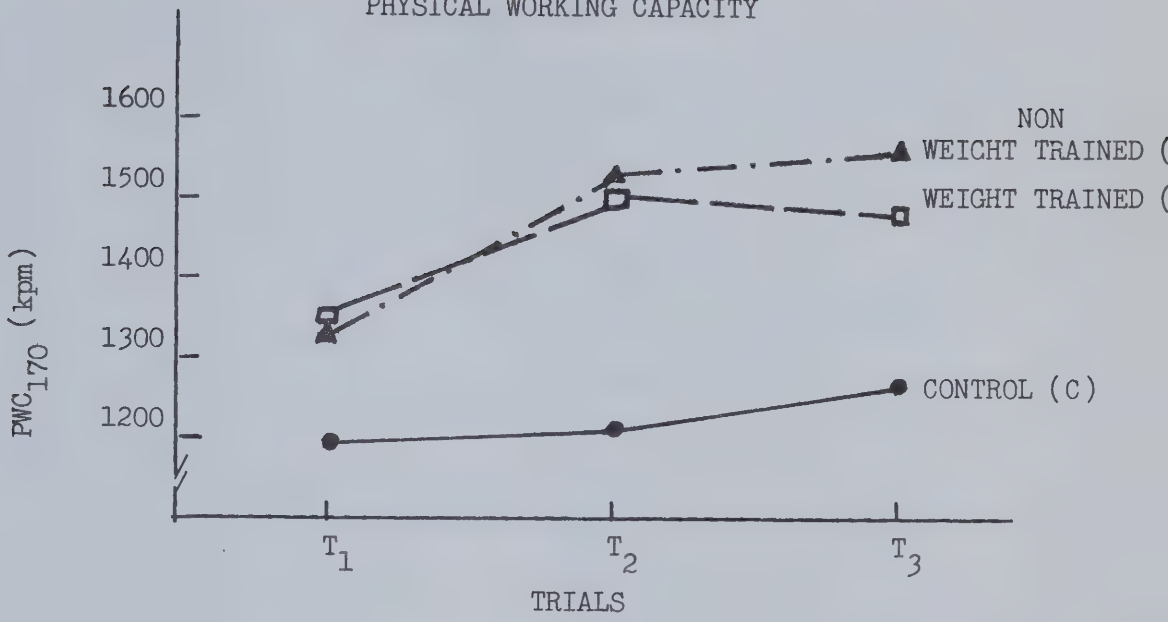


FIGURE 2

MAXIMAL O_2 INTAKE (lit/min)

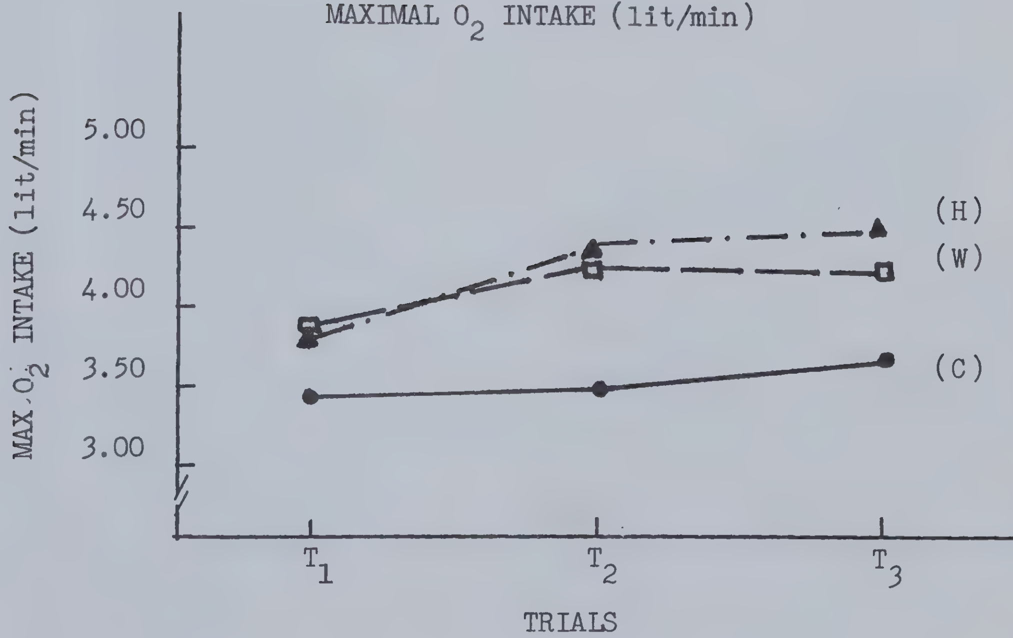


FIGURE 3

MAXIMAL O_2 INTAKE (ml/kg/min)

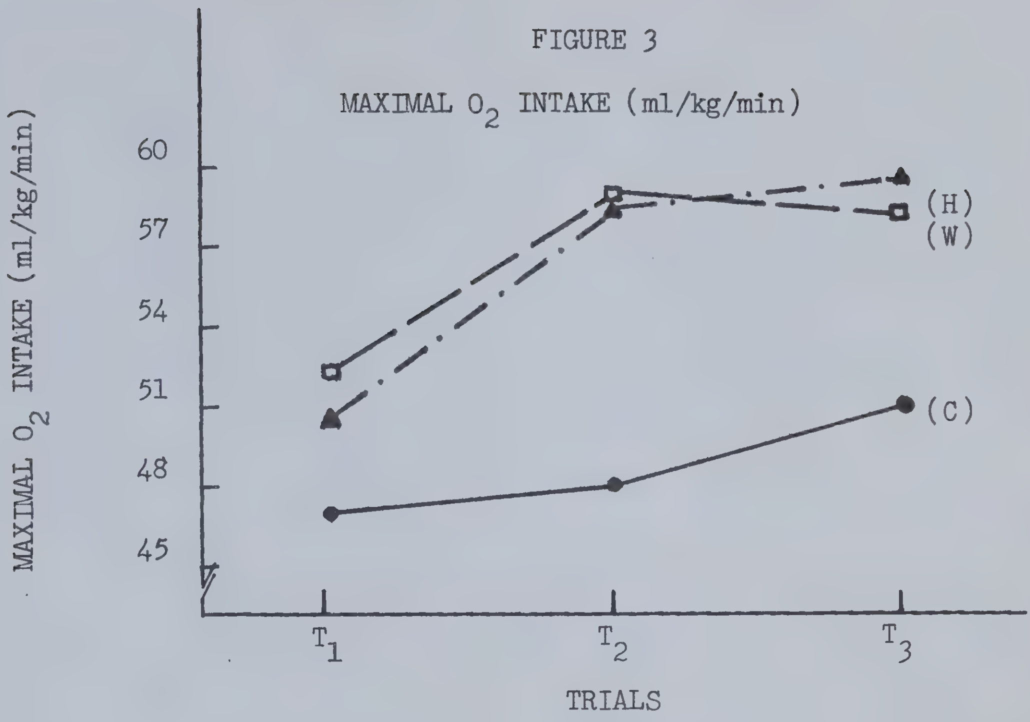


FIGURE 4

ARM STRENGTH INDEX

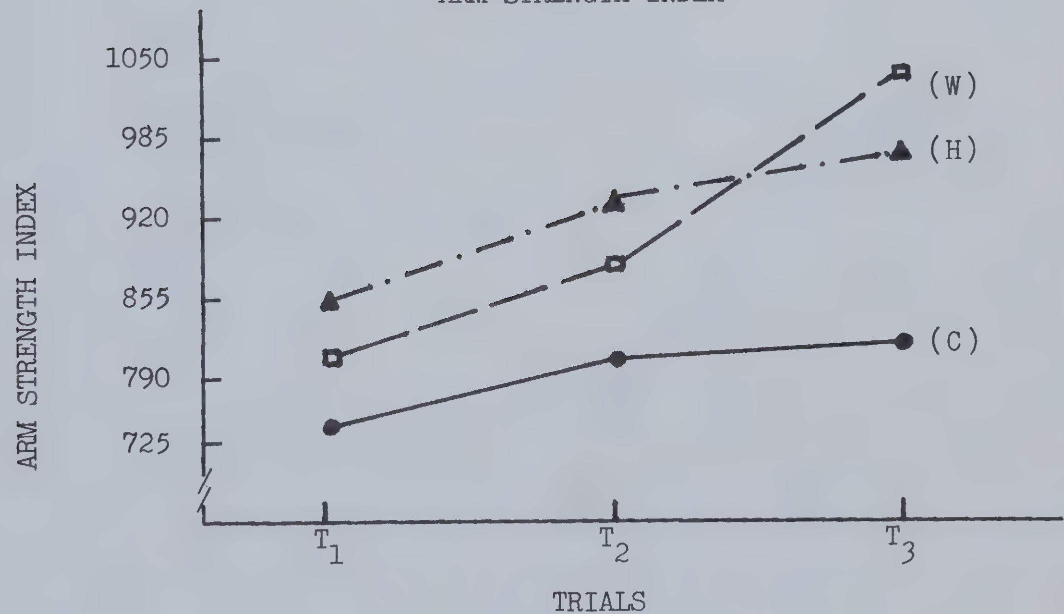


FIGURE 5

STRENGTH INDEX

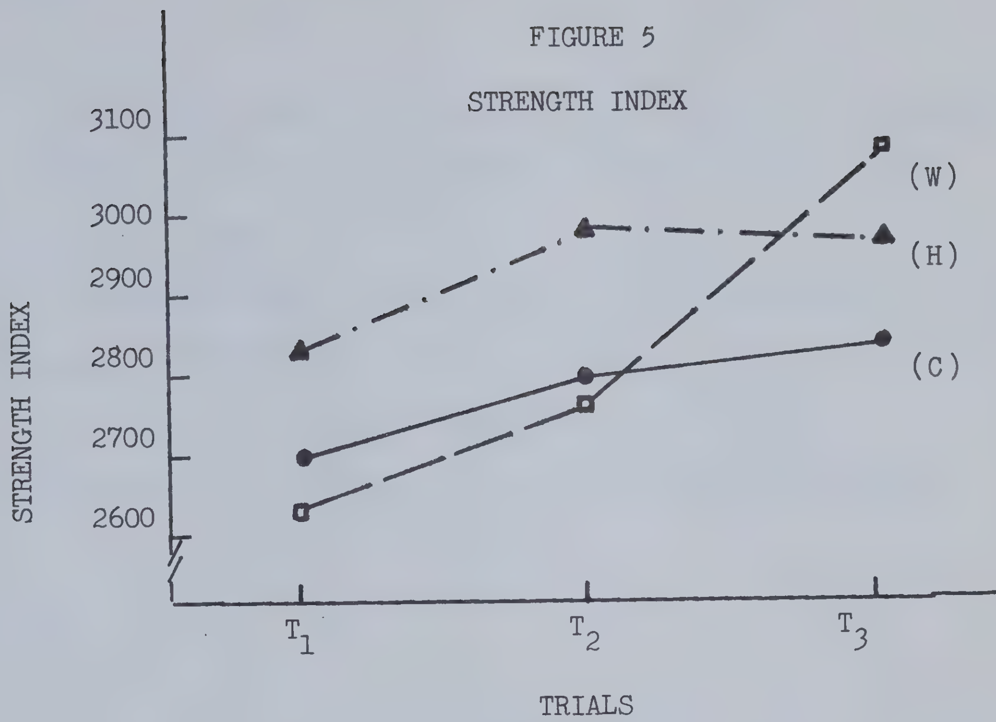
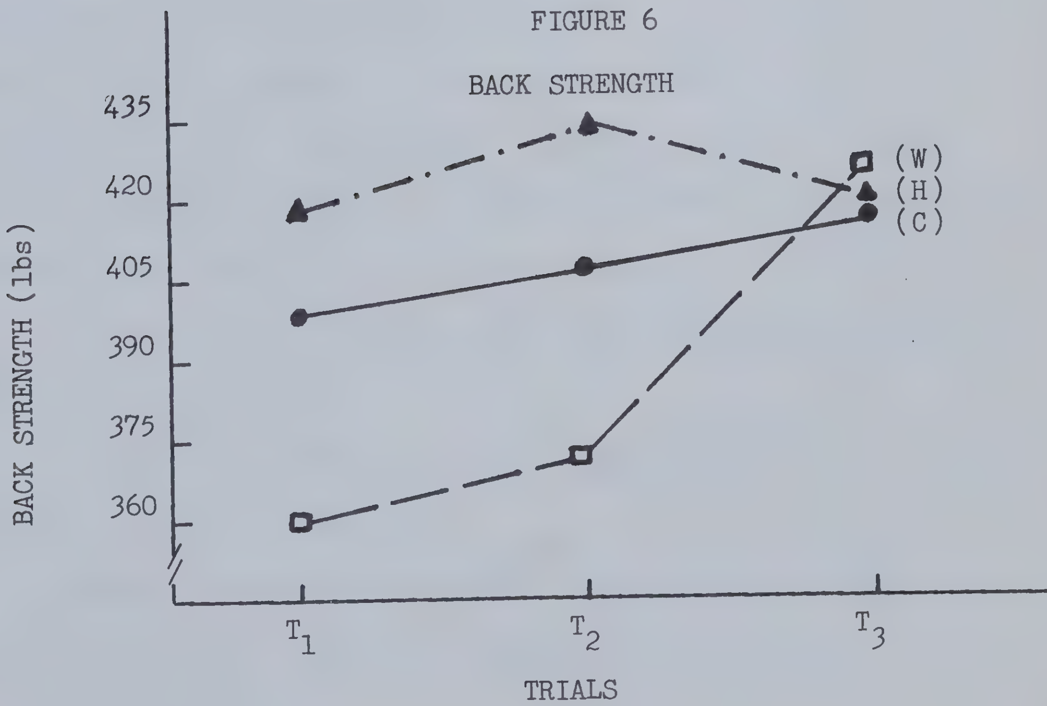


FIGURE 6

BACK STRENGTH



Control Group

The control group underwent no changes in any of the variables studied, with the exception of an increase in vital capacity between trials one and two (Figures 1 to 12).

The control group differed from the two hockey groups in PWC_{170} MVO_2 (liters/min), and MVO_2 (ml/kg/min) on all three trials (Tables 42 to 44). There were no differences between the control group and the hockey group on back strength or leg strength throughout the season.

Hockey Group

The non-weight training hockey group increased in PWC_{170}, MVO_2 (liters/min) and MVO_2 (ml/kg/min) from trial one to trial two, (Figures 1 to 3), but remained at that level for the remainder of the season (Tables 42 to 44). Arm strength increased significantly from trial one to trial three; however, no differences were observed between pre- and mid-season values or mid- and post-season values (Table 45).

The chin-ups of the non-weight trained hockey players changed from trial two to trial three (Table 51).

A significant decrease in right grip strength was noted between trials one and two (Table 50).

The back strength, leg strength, strength index, shoulder-dips, left grip strength, and vital capacity of this group remained the same during the season.

FIGURE 7

LEG STRENGTH

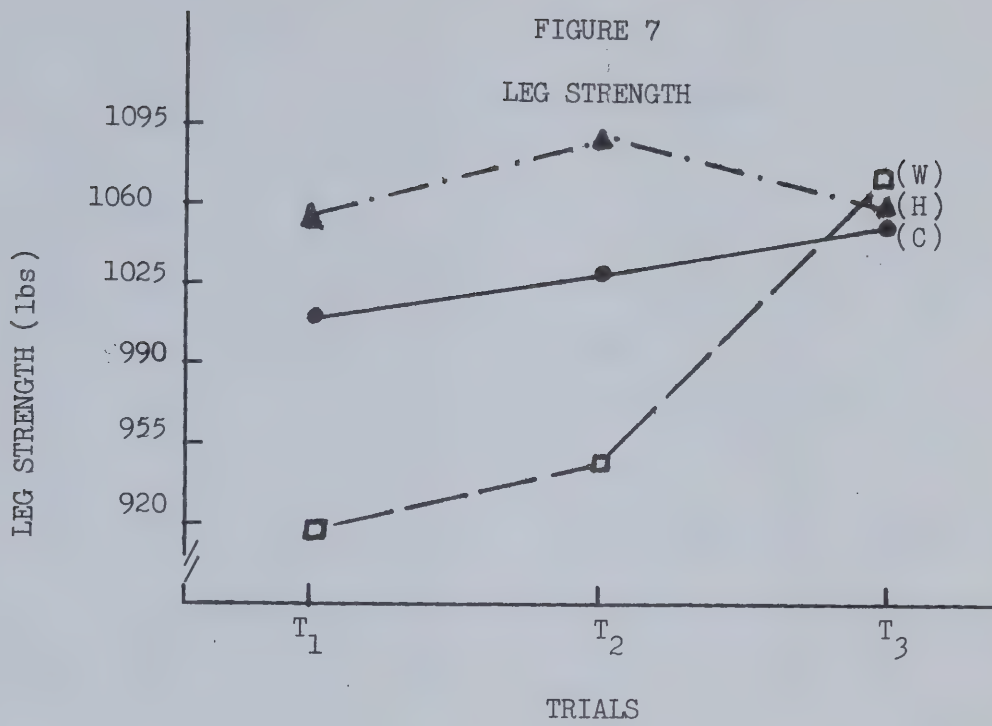


FIGURE 8

LEFT GRIP STRENGTH

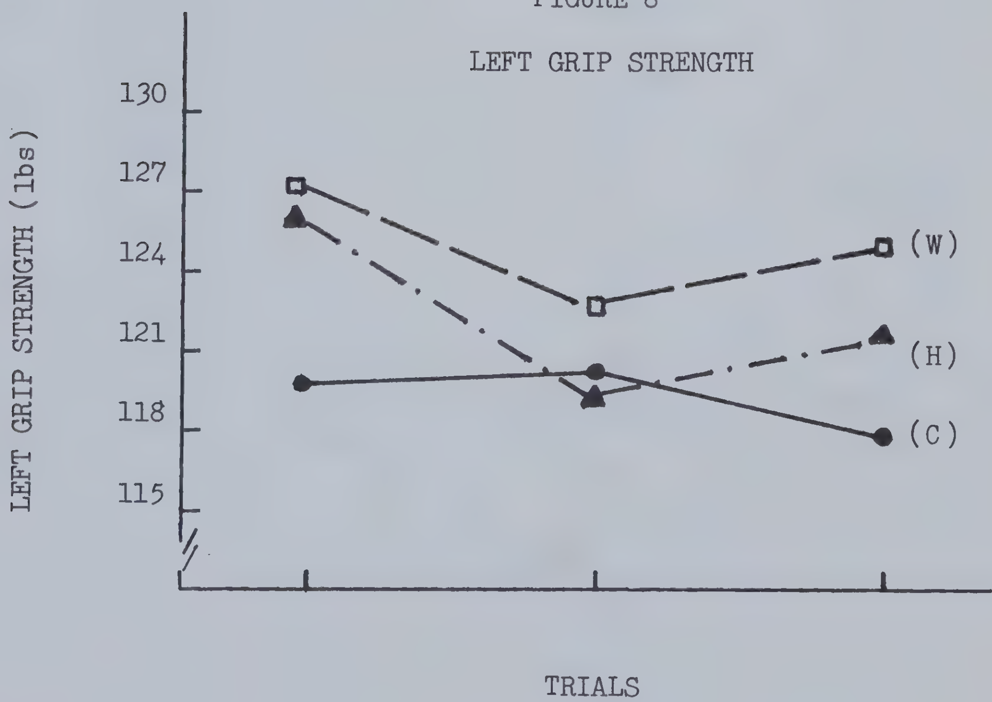


FIGURE 9

RIGHT GRIP STRENGTH

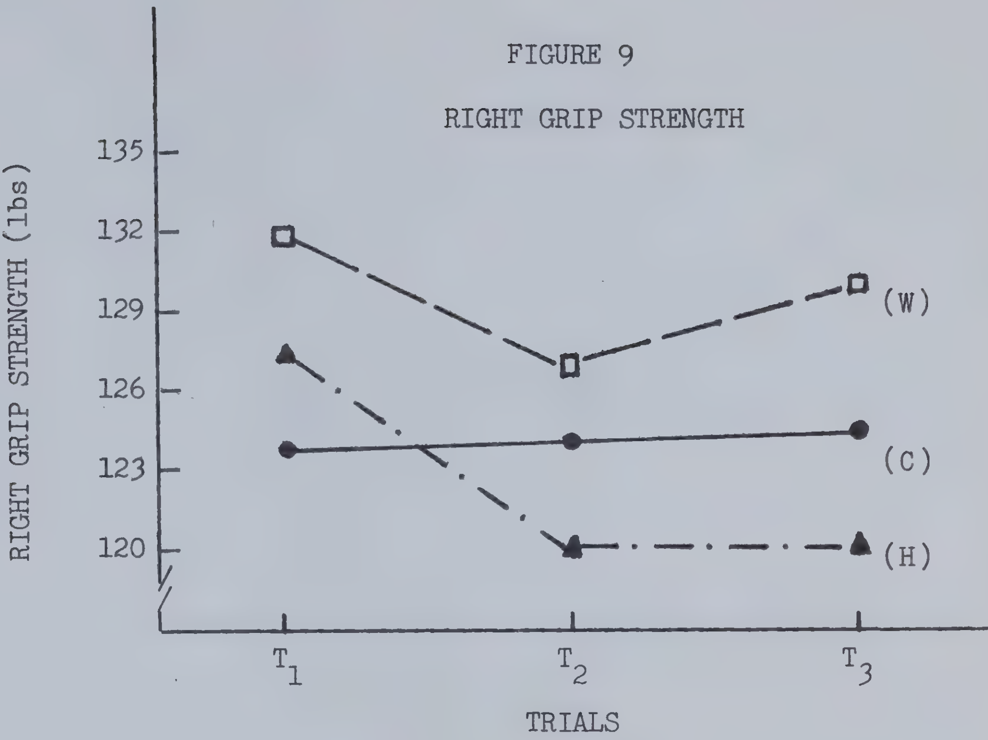


FIGURE 10

CHIN-UPS

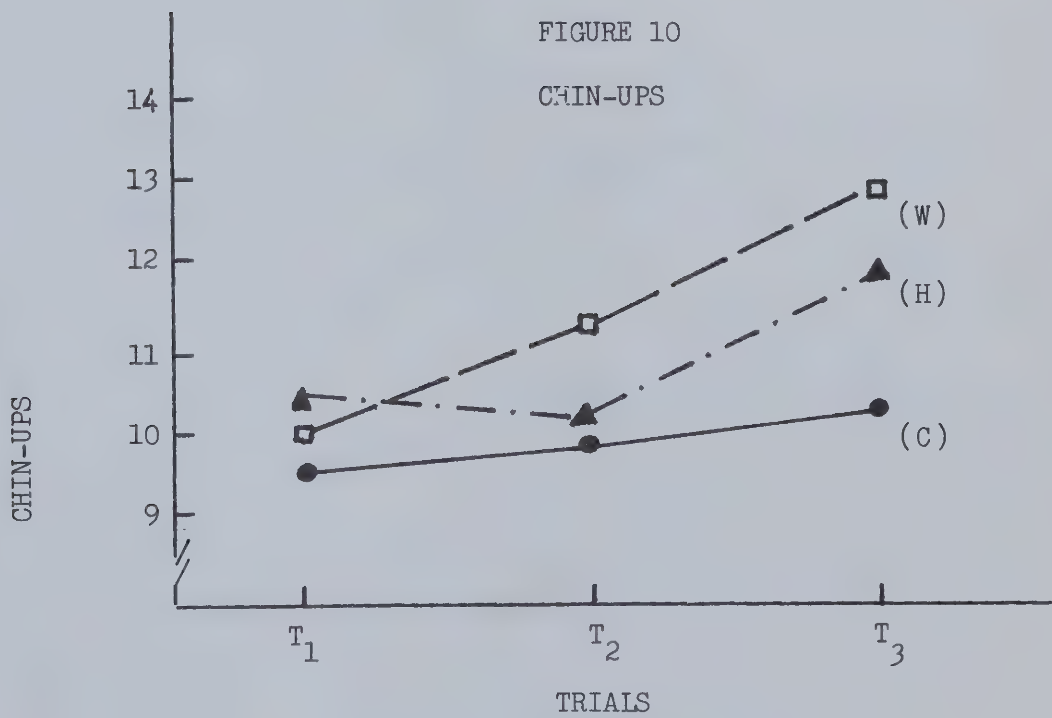


FIGURE 11

SHOULDER DIPS

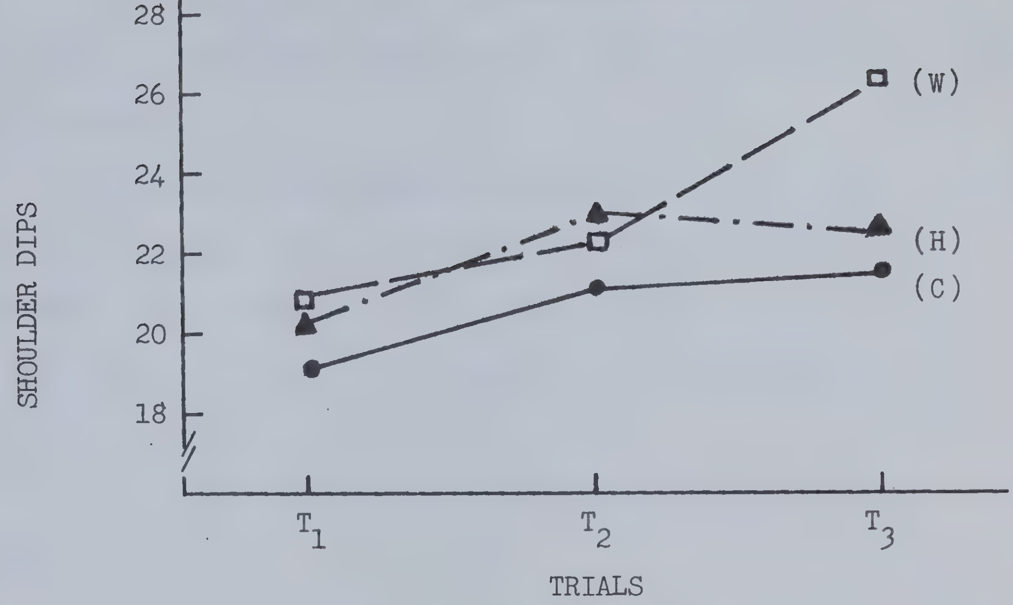
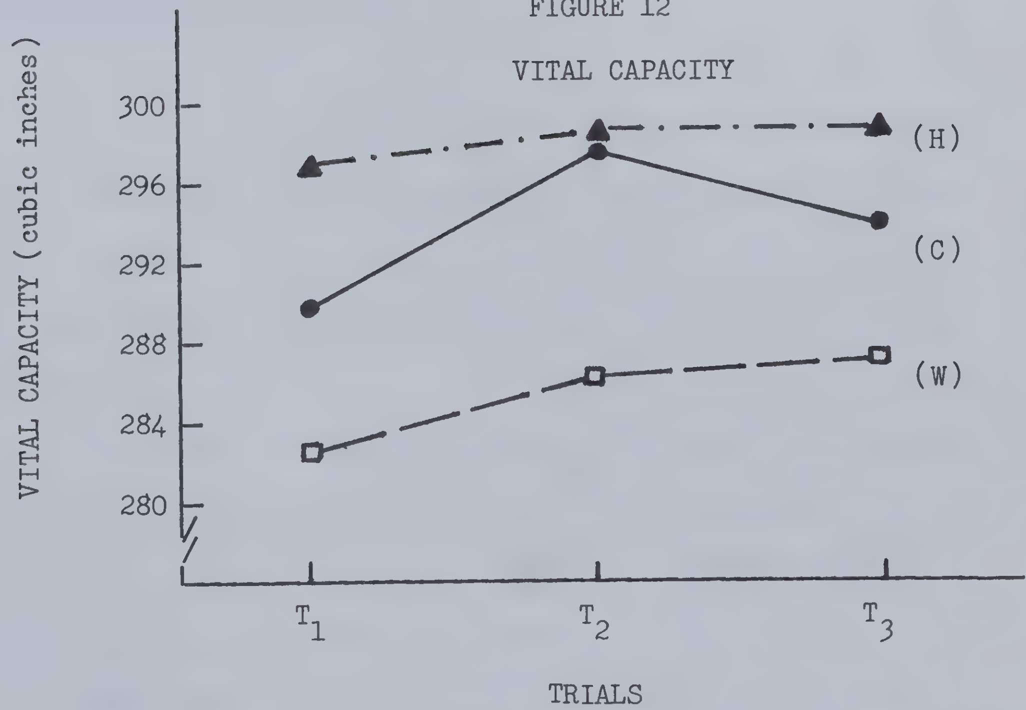


FIGURE 12

VITAL CAPACITY



Weight Trained Group

The hockey players that weight-trained showed an identical pattern with the non-weight-trained group in PWC_{170} and MVO_2 during the season (Figures 1 to 3)

The weight-trained group remained at the same level in back strength, leg strength, strength index, arm strength, chin-ups and shoulder dips from trial one to trial two. However, a significant change was observed for all these parameters between trial two and trial three. (Tables 45, 46, 47, 48, 51 & 52).

No changes occurred in grip strength or vital capacity during the season.

Fitness-Performance Correlations:

The performance rating from the preference test correlated ($r = .552$) significantly with body weight only for the senior team ($p = .05$) (Table 67). No significant correlations were observed between the performance rating and fitness parameters of the junior players (Table 66).

Body weight of the junior players correlated significantly with PWC_{170} ($r = .666$) and maximum O_2 intake when expressed in liters per minute ($r = .683$); while that of the senior players correlated significantly only with maximum O_2 intake ($r = .574$).

Significant correlations of $r = .806$ and $r = .998$ were observed between the PWC_{170} and Max VO_2 (liters/min) for the senior and junior values. The PWC_{170} values of both groups also correlated

significantly with Max VO_2 expressed in ml/kg/min.

The strength index of the junior hockey players correlated ($p = .05$) with PWC_{170} ($r = .562$), Max VO_2 (liters/min) ($r = .575$), and arm strength index ($r = .727$), but no relationship between these measurements were observed in the senior hockey players.

All other correlations examined were insignificant (Appendix C).

CHAPTER V

DISCUSSION

Physical Working Capacity

Both groups of hockey players underwent significant changes in physical working capacity during the season while the control group remained relatively the same. The non-weight-trained hockey players increased 16% in PWC_{170} from a preseason value of 1339 kpm to a mid-season value of 1552 kpm ($p = .01$); then increased a further 2% to a postseason value of 1585 kpm.

The weight-trained hockey group experienced a 13% increase, from 1354 kpm to 1526 kpm, followed by a 1% decrease in the latter part of the season.

The PWC_{170} of the control group increased nonsignificantly from 1200 kpm to 1314 kpm, and finished at 1278 kpm during the season.

The PWC_{170} scores obtained in several other studies are presented in Table one. Tornvall (1963) and Hellstrom (1961) investigated the physical working capacity of military conscripts and reported mean PWC_{170} values of 1064 kpm and 929 kpm. Wendelin et al (1965) reported a mean PWC_{170} value of 1107 kpm for 153 medical students. This value is quite similar to the 1143 kpm value obtained by Miki (1969) for 54 Physical Education students. De Vries and Klafs (1965), Fedoruk (1969), and Holmgren et al (1967) also studied the physical working capacity of Physical Education majors and cited means of 1266 kpm, 1345 kpm, and 1400 kpm.

TABLE 1

A COMPARISON OF PHYSICAL WORKING CAPACITY STUDIES*

INVESTIGATOR	SUBJECTS	N	AGE	WEIGHT	PWC_{170} (kpm/min)
Miki (1969)	P. E. majors	54	22.4 ± 1.35	75.96 ± 10.71	1143 ± 186.8
deVries & Klafs (1965)	P. E. majors	16	22.4	78.5	1266 ± 276
Fedoruk	P. E. majors	24	19.97	76.1	1345
Holmgren et al (1967)	P. E. majors (Swedish)	10		71.6 ± 9.0	1400 ± 237.7
Wendelin et al (1965)	Medical Students	153	21.5	69.5	1107 ± 301
Tronvall (1963)	Military Conscripts	89	19.5	68.3	1064 ± 218
Tornvall (1963)	Middle Distance Runners	23	22.5 ± 3.3	69.3	1551 ± 151
Hellstrom (1961)	Middle Distance Runners	48		66.3 ± 4.5	1607 ± 174

* Adapted from Miki (1969) p. 94

The difference in the PWC_{170} scores listed above may be due to sample variation in regards to:

1. lean body weight
2. superior cardiorespiratory fitness and/or,
3. mechanical efficiency (Miki, 1969).

The difference between the PWC_{170} of the military conscripts and the Physical Education majors may be attributed to heavier body mass of the students and higher cardio-vascular efficiency. Miki (1969) reasoned that the higher physical working capacity (1400 kpm) of the Swedish Physical Education majors was due to a higher level of fitness and an advantage in pedalling efficiency compared to the North American students examined in other studies (deVries and Klafs, 1965; Miki, 1969; Fedoruk, 1969).

The physical working capacity of highly-trained middle distance runners (1551 kpm ± 151 kpm and 1607 kpm ± 174 kpm) have been reported by Tornvall (1963) and Hellstrom (1961). The thirty hockey players studied in the present study improved from an initial mean PWC_{170} score of 1346 kpm to a midseason value of 1539 kpm, and a postseason value of 1545 kpm. This initial value of 1346 kpm is similar to the 1345 kpm reported by Fedoruk (1969) for twenty-four first year Physical Education students. The midseason and postseason values for the hockey players in the present study were comparable with the 1551 kpm value of the middle distance runners studied by Tornvall (1963), but below the value of 1607 kpm obtained for another group of distance runners (Hellstrom, 1961). The weight of the hockey players was greater than that of the middle distance runners, therefore, the runners exhibited superior cardiorespiratory fitness. This greater efficiency is evident when the physi-

cal working capacity is adjusted for body weight. The postseason PWC_{170} of the hockey players (20.4 kpm/Kg.) is below that reported for the middle distance runners (22.4 kpm/Kg. and 24.3 kpm/Kg).

Hellstrom (1961) reported an 18 percent improvement in PWC_{170} for 88 young military conscripts following a three month training period (1273 kpm to 1502 kpm). The hockey players in the present study showed a 15 percent improvement in physical working capacity during the season.

Maximal Oxygen Intake

Maximal O_2 intake values of the two hockey groups improved significantly ($p = .01$) from preseason to midseason, then remained unchanged for the rest of the season. Table two presents a summary of the changes in maximal O_2 intake during the season. The control subjects showed a tendency to improve during the season, but no significant change was observed. The thirty hockey players demonstrated mean O_2 intake values of 3.84 liters/min., 4.38 liters/min., and 4.40 liters/min. at the three testing sessions during the season.

Figures 2 and 3 show that both hockey groups levelled off in maximal O_2 intake during the second half of the season. The hockey group that weight-trained dropped slightly from 4.34 to 4.28 liters/min. between trial two and three, while the other hockey group increased slightly from 4.4 to 4.51 liters/min.

TABLE 2

CHANGES IN MAXIMAL O_2 INTAKE DURING A SEASON OF ICE HOCKEY

Group	N	Maximal O_2 Intake Trial 1	Trial 2	Trial 3
Control	16	3.43+ 46.19++	3.48 47.43	3.69 50.12
Hockey (non weight training	15	3.82 49.67	4.41** 58.12**	4.51 59.32
Hockey (weight training)	15	3.85 51.53	4.34** 58.39**	4.28 57.37
Hockey (total)	30	3.84 50.60	4.38* 58.25*	4.40 58.34

* $p = .05$

** $p = .01$

+liters/minute

++ml/kg/min

Table three presents a summary of studies reporting the maximal O_2 intake of other ice hockey players. The postseason value of 4.40 liter/min., or 58.34 ml/Kg/min. observed for the 30 hockey players in the present study agrees closely with the values presented in Table three. Only the value of 62.2 ml/Kg/min., reported by Nellson for 18 O.H.A. junior A hockey players, is higher than the peak value obtained in the present study. Results of the present study showed an improvement in the aerobic capacity of hockey players at the University of Alberta compared with the 1965 seasonal values presented by Watson (1965) of 4.11 liters/min. or 54.26 ml/Kg/min.

Green (1973) observed that only minimal seasonal changes (3%) occurred in aerobic capacity with the 18 players studied. Another study by Green et al (1972b) reported a similar change of 4% during the season. The findings of the present study in regards to aerobic capacity (15% seasonal increase) concurs with those of Watson (1965) who reported a 17.46% improvement during the year. This would indicate that University of Alberta ice hockey players received a more adequate training stimulus during the season than the players studied by Green et al (1972b) and Green (1973).

Green concluded that intercollegiate hockey players measured well below endurance athletes in aerobic capacity. A value of 65.8 ml/Kg/min. (Buskirk et al, 1957) was reported for five cross country runners about twenty years of age. One of the highest aerobic capacities ever recorded was 85 ml/Kg/min. for a Swedish cross country skier (Saltin and Astrand, 1967). The aerobic capacity of most ice hockey teams studied has ranged between 53 - 58 ml/Kg/min. This would tend to support Green's

conclusion. The highest aerobic capacity reported for an ice hockey team has been the 62.2 ml/Kg/min. (Nielson, 1974). This particular team participated in a supplementary jogging program along with the on-ice conditioning sessions during the ice hockey season. The high degree of aerobic capacity attained by this group can be attributed to a great extent to the jogging program emphasizing again the need for better training of ice hockey players, in terms of maximal O_2 intake.

TABLE 3

MAXIMAL O_2 INTAKE OF ICE HOCKEY PLAYERS

Investigator	Subjects	N	Maximal O_2 Uptake liters/min	ml/kg/min
Watson (1965)	Intercollegiate	10	4.11	54.26
Howell (1966)	Intercollegiate	-	-	57.0
Ferguson et al (1969)	Intercollegiate	-	-	55.0
Green et al (1972b)	Intercollegiate	20	4.18	56.4
Green et al (1972c)	Intercollegiate	8	4.04	53.4
Neilson (1974)	Junior A	14	-	62.2
Green (1973)	Junior A	18	4.43	57.1
Present Study	Intercollegiate	30	4.40	58.34

Muscular Strength and Endurance

As mentioned previously, the control group did not change significantly on arm strength, strength index, back strength, leg strength, chin-ups of shoulder-dips during the hockey season. Both hockey groups demonstrated no significant change in arm strength, strength index, back strength, leg strength, chin-ups and shoulder dips from preseason to midseason values. The right and left grip strength of the weight-trained group remained the same throughout the study, as did the left grip strength of the non-weight-trained group. The right grip of the non-weight-trained group decreased significantly ($p = .01$) between trial one and two, then remained relatively the same.

The in-season weight-training program was conducted during the second half of the season. The effectiveness of this program to develop and maintain muscular strength and endurance was assessed by a comparison of the means for the two hockey groups between trial two and three. The non-weight-trained group failed to make any significant improvement in arm strength, strength index, back strength, leg strength, left and right grip strength, and shoulder-dips. An increase in chin-ups from 10.57 to 12.40 was the only significant change measured in strength or endurance for the non-weight-trained group between trial two and three ($p = .01$). An overall increase in arm strength index was noted preseason and postseason values ($p = .01$).

Significant increases were observed for the weight-trained group in arm strength index, strength index, leg strength, chin-ups and shoulder-dips ($p = .05$). Back strength increased from 397 pounds

TABLE 4

MUSCULAR STRENGTH AND ENDURANCE CHANGES BETWEEN TRIAL TWO AND TRIAL THREE

Group	Arm Strength Index			Strength Index			Back Strength			Leg Strength		
	T_2	T_3	D	T_2	T_3	D	T_2	T_3	D	T_2	T_3	D
Control	795.8	819.1	23.3	2797	2838	41	412.8	422.8	10	1038	1060	22
Hockey (non weight trained)	933.3	970.3	37.0	2992	2974	18	414.3	395	19.3	1104	1066	38
Hockey (weight trained)	993.3	1046	162.7**	2758	8095	337**	397	421.3	24.3	952	1087	135*

TABLE 4 (cont.)

Group	Chin-ups			Shoulder Dips		
	T_2	T_3	D	T_2	T_3	D
Control	10.09	10.59	0.5	21.37	21.81	0.44
Hockey (non weight trained)	10.57	12.40	1.83**	23.63	23.10	0.53
Hockey (weight trained)	11.67	13.53	1.86**	22.40	26.90	4.50**

* p = .05
** p = .01

at T_2 to 421.3 pounds, but this was not a significant change. A seasonal increase in back strength was noted, however, between trial one and trial three.

Table four summarized the changes which occurred in muscular strength and endurance during the second half of the season. Chin-ups and shoulder-dips increased 15.9% and 20.0% respectively for the weight-trained group. The arm strength index, which is a measure of dynamic endurance, increased 18.4% from 883.3 to 1046. These increases in chin-ups, shoulder-dips and arm strength index are highly significant ($p = .01$), however, they were well below the improvements reported by Dennision et an (1961) for a similar weight-training program.

Dennison et al had an experimental group of ten University of British Columbia undergraduates employ a weight-training program twice a week for eight weeks. They reported a 66% increase in shoulder-dips (6.2 to 10.3), a 64% increase in chin-ups (5.3 to 8.7) and a 71% increase in arm strength index (321 to 550.1), which were significant at the .02, .01 and .01 level of confidence, respectively. The greater increases reported by Dennison et al can be attributed to the low initial values, longer program and stricter control over the weight-training sessions. The university undergraduates probably had not had as much weight-training experience as the hockey players of the present study; therefore, the students started at a lower percentage of their maximum strength and endurance capacities. Not all of the hockey players in the weight-trained group were able to complete the fourteen training sessions, due to on-ice practice sessions and academic commitments. This would have detracted from the upper body endurance gains measured by the chin-ups,

shoulder-dips and arm strength index.

Cureton (1943) found a 28% increase in chin-ups and a 49.3% increase in shoulder-dips following a one-hour physical conditioning class carried out twice-weekly over a period of 12 weeks. Kistler (1944) conducted a conditioning program one half hour, three times a week, for eight weeks. He found a 8% increase in chinning and a 17.6% increase in shoulder-dips.

Capen (1950) reported increases of 27.9% in chinning and 16.4% in dipping after a weight-training program. Scott (1964) reported an insignificant increase of 5.5% in chin-ups and a significant increase of 22.6% in shoulder dips following a twice-weekly conditioning program that lasted for eight weeks. Scott also reported a significant ($p = .05$) increase in left grip strength from 107.4 pounds to 117.67 pounds, and a significant increase in leg strength from 469.9 to 520.1 pounds. Back strength increased from 341 pounds to 349 pounds, a 2.4% difference.

Back strength and leg strength of the weight-trained group in the present study increased from 397 to 421.3 pounds, and 952 pounds to 1087 pounds, between trials two and three. This was a nonsignificant 6.1% rise in back strength and a significant 14.2% increase in leg strength ($p = .01$). These results concur closely with those of Tuttle et al (1955) and Miki (1969). Tuttle et al found a back strength of 368 ± 73 pounds and a leg strength of 1107 ± 381 pounds for a group of twenty-three subjects aged 24 to 46 years of age. Miki reported a mean back strength of 527.4 ± 77 pounds and a mean leg strength of 1140 ± 189 pounds for fifty-four undergraduate Physical Education majors at the University of British Columbia.

TABLE 5

COMPARISON OF STRENGTH AND ENDURANCE LEVELS OF THE TWO HOCKEY GROUPS

Parameter	Trial 1			Trial 2			Trial 3		
	Weight	Hockey	Diff.	Weight	Hockey	Diff.	Weight	Hockey	Diff.
Arm Strength Index	794.5	851.7	57.2	883.3	933.3	50	1046	970	75.5*
Strength Index	2622	2833	211*	2758	2992	234*	3095	2974	121
Back Strength	365.3	390	24.7	397	414.3	17.3	421.3	395	26.3
Leg Strength	921.7	1065	143.3*	952	1104	152*	1087	1066	21
Chin-ups	10.23	10.67	0.44	11.67	10.57	1.10	13.53	12.40	1.13*
Shoulder Dips	20.93	20.77	0.16	22.40	23.63	1.23	26.90	23.10	3.80*
Right Grip Strength	132.5	128	4.5	127.3	120.3	7.0*	130.4	120.3	10.1**
Left Grip Strength	128	126.6	1.4	123.1	120.1	3.0	125.3	122.1	3.2

* p = .05
** p = .01

Further evaluation of the weight-training program employed in the present study is possible by comparing the means of the weight-trained and non-weight-trained hockey groups. No significant difference between the two groups existed at trial one or two for the following muscular strength and endurance measures: shoulder-dips, chin-ups, and arm strength index. However, following the weight-training program, the postseason values of the weight-trained group were significantly ($p = .01$) greater than those of the group that did not weight-train for these three parameters.

The means of the two groups for leg strength and strength index were significantly different at trial one and trial three, with the non-weight-trained group having the larger mean. Postseason differences for leg strength and strength index were not significant, indicating that the weight-training program was effective in reducing the difference between the two hockey groups. Table five gives the comparison of means for the two experimental hockey groups.

Muscular strength and endurance levels observed in the present study concur closely with those reported by Neilson (1974) for Peterborough Petes Junior hockey players. Neilson found a mean post-season back strength value of 426 pounds compared to 421 (weight-trained) and 395 (non-weight-trained) observed in the present study. The leg strength of the weight-trained group (1087 lbs.) was higher than the 1066 of the non-weight-trained group and the 1018 reported by Neilson. The right and left grip strengths (130 pounds and 125 pounds) of the weight-trained group in the present study concurred with the O.H.A. junior team (137 pounds and 124 pounds). The other hockey group studied in the present study demonstrated somewhat lower (120 pounds and 122 pounds) values for right and left grip strength.

Fitness-Performance Relationships

As mentioned in Chapter IV, the correlation between the performance scores of the senior hockey players with their body weight was the only significant relationship found. Correlations comparing the performance score with the fitness measures: PWC_{170}, Maximum O_2 intake, arm strength index and strength index were not significant for either group. The results of the present study indicated that body weight was closely associated with performance, at least in the senior team, while the fitness measures studied were not related to performance as measured by the paired-performance test.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Seasonal Fitness Changes

Fitness appraisal was conducted three times during the 1973-4 season on thirty intercollegiate hockey players at the University of Alberta to observe inseason fitness changes. Physical working capacity, maximal O_2 intake, grip strength, back strength, leg strength, arm strength index, strength index, chin-ups, shoulder dips, and vital capacity were the fitness measures examined. Subjects were tested in October (preseason), January (midseason), and March (postseason). Sixteen moderately-active undergraduates from the university acted as control subjects for the experiment.

This study revealed that the hockey players examined increased significantly in physical working capacity and maximal O_2 intake between pre and midseason testing, then remained at that same level for the rest of the season. The control group increased slightly on mid and post season measures of PWC_{170} and Max VO_2, but not significantly.

Muscular strength and endurance were evaluated by the grip strength, back strength, leg strength, arm strength index, chin-ups, shoulder dips and strength index. The hockey players did not show any improvement in arm strength index, strength index, back strength, leg strength, chin-ups or shoulder dips between pre and midseason testing.

Weight Training

The hockey players were split into two groups to evaluate the effectiveness of an in-season weight training program conducted during the second half of the season. The non-weight-trained hockey group demonstrated no change in arm strength index, back strength, leg strength, grip strength or shoulder dips between mid and postseason testing. An increase in chin-ups was measured between trial two and trial three.

The hockey group that did participate in the weight training program improved significantly in arm strength index, strength index, leg strength, chin-ups and shoulder dips during the second half of the season. Back strength increased nonsignificantly between trials two and three, resulting in a significant improvement between trials one and three.

The control group remained unchanged on all strength and endurance measures over the three testing sessions.

<u>Fitness and Performance</u>

An attempt was made to relate playing performance of the hockey players to the various fitness measures taken. Scores obtained from a paired preference test completed by the hockey groups were correlated with postseason values of PWC_{170}, Max VO_2, arm strength index, strength index and body weight.

It was found that body weight correlated significantly with the performance score ($r = .552$), whereas PWC_{170}, Maximal O_2 intake, arm strength, and strength index did not.

Conclusions

Within the limitations of the present study, the following conclusions can be drawn:

1. a season of intercollegiate ice hockey significantly improved the physical working capacity and oxygen intake of the players studied.

2. improvement in physical working capacity and maximal O_2 intake was confined to the first half of the season.

3. back strength, leg strength, strength index, shoulder dips and grip strength are not changed by a season of intercollegiate hockey; arm strength index and chin-ups may be improved by this type of hockey program.

4. an inseason weight-training program can make a significant contribution to the muscular strength and endurance of intercollegiate ice hockey players.

5. the hockey players in the present study compare favourably in Maximum O_2 intake and strength and endurance measures to players previously studied.

6. the players in this study were lower in Maximum O_2 intake than endurance athletes previously studied.

7. playing performance as measured by a paired-preference test was not closely related to physical working capacity, maximum O_2 intake, arm strength index or strength index.

8. playing performance at the intercollegiate level was associated with body weight for the senior players studied.

Recommendations

1. Further study be done to determine if the peak values for physical working capacity and maximal O_2 intake obtained in this study at midseason are representative of the training pattern for intercollegiate hockey teams.

2. Improved aerobic training methods be utilized in training intercollegiate hockey players to increase aerobic capacity, especially during the second half of the season.

3. The effectiveness of inseason weight-training programs should be compared to that of preseason programs for increasing strength and endurance.

4. Further investigation should be undertaken to relate playing performance to fitness parameters, game skills and motivational factors.

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APPENDIX A

ANALYSIS OF VARIANCE TABLES

TABLE 6

ANALYSIS OF VARIANCE

FOR PWC_{170}

SOURCE OF VARIANCE	SS	DF	MS	F	P
Between Subjects	**********	45			
'A' Main Effects	**********	2	941085.500	8.483	0.0007858
Subjects Within Groups	**********	43	110931.312		
Within Subjects	**********	92			
'B' Main Effects	664728.500	2	332364.250	20.453	0.0000007
'A*B' Interaction	203928.500	4	50982.125	3.137	0.0185172
'B'.Subj. Within Groups	**********	86	16250.043		

TABLE 7

ANALYSIS OF VARIANCE

FOR OXYGEN INTAKE (liters/min.)

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	50.194	45			
'A' Main Effects	14.007	2	7.033	8.392	0.0008362
Subjects Within Groups	35.886	43	0.835		
Within Subjects	17.631	92	2.754		
'B' Main Effects	5.508	2	0.381	22.114	0.0000007
'A*B' Interaction	1.522	4	0.125	3.056	0.0209395
'B'.Subj. Within Groups	10.711	86			

TABLE 8

ANALYSIS OF VARIANCE

FOR OXYGEN INTAKE (ml/Kg/min.)

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	5495.875	45			
'A' Main Effects	1873.065	2	936.532	11.243	0.0001178
Subjects Within Groups	3581.812	43	83.298		
Within Subjects	3139.437	92			
'B' Main Effects	1122.786	2	561.393	27.294	0.0000001
'A*B' Interaction	268.983	4	67.246	3.269	0.0151687
'B'·Subj. Within Groups	1768.875	86	20.568		

TABLE 9

ANALYSIS OF VARIANCE

FOR ARM STRENGTH

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	**********	45			
'A' Main Effects	504015.312	2	252007.625	2.380	0.1046596
Subjects Within Groups	**********	43	3105896.125		
Within Subjects	**********	92			
'B' Main Effects	513405.936	2	256702.937	27.895	0.0000013
'A*B' Interaction	147400.812	4	36850.203	4.004	0.0050086
'B'.Subj. Within Groups	791408.000	86	9202.418		

TABLE 10

ANALYSIS OF VARIANCE

FOR STRENGTH INDEX

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	**********	45			
'A' Main Effects	587765.062	2	293882.500	0.842	0.4376370
Subjects within Groups	**********	43	348844.625		
Within Subjects	**********	92			
'B' Main Effects	**********	2	731029.500	18.576	0.0000001
'A*B' Interaction	749290.187	4	187322.500	4.760	0.0016210
'B' . Subj. Within Groups	**********	86	39352.555		

TABLE 11

ANALYSIS OF VARIANCE

OF BACK STRENGTH

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	376912.000	45			
'A' Main Effects	8134.465	2	2067.232	0.474	0.6254637
Subjects within Groups	368640.000	43	8573.020		
Within Subjects	166704.000	92			
'B' Main Effects	28965.105	2	9482.551	6.045	0.0034984
'A*B' Interaction	13297.020	4	3324.255	2.119	0.0853131
'B' . Subj. within Groups	134912.000	86	1568.744		

TABLE 12

ANALYSIS OF VARIANCE

FOR LEG STRENGTH

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	**********	45			
'A' Main Effects	193174.437	2	96587.188	0.903	0.4127689
Subjects within Groups	**********	43	106924.625		
Within Subjects	**********	92			
'B' Main Effects	112120.812	2	45060.406	3.648	0.0301439
'A*B' Interaction	154861.250	4	38715.312	2.520	0.0469559
'B' . Subj. within Groups	**********	86	15365.578		

TABLE 13

ANALYSIS OF VARIANCE FOR LEFT GRIP

STRENGTH

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	20458.000	45			
'A' Main Effects	867.447	2	433.723	0.953	0.3937229
Subjects within Groups	19578.000	43	455.302		
Within Subjects	4410.000	92			
'B' Main Effects	327.447	2	163.723	3.656	0.0299236
'A*B' Interaction	239.362	4	59.840	1.336	0.2630159
'B' . Subj. within Groups	3851.000	86	44.779		

TABLE 14

ANALYSIS OF VARIANCE FOR RIGHT GRIP STRENGTH

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	23696.000	45			
'A' Main Effects	1304.042	2	652.021	1.251	0.2964588
Subjects within Groups	22414.000	43	521.256		
Within Subjects	4371.000	92			
'B' Main Effects	428.936	2	214.468	5.518	
'A*B' Interaction	382.979	4	95.745	2.303	0.0649615
'B' . Subj. within Groups	3576.000	86	41.581		

TABLE 15

ANALYSIS OF VARIANCE FOR CHIN-UPS

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	1519.906	45			
'A' Main Effects	63.655	2	31.828	0.940	0.3983272
Subjects Within Groups	1455.223	43	33.842		
Within Subjects	296.836	92			
'B' Main Effects	92.008	2	46.004	22.251	0.0000007
'A*B' Interaction	29.236	4	7.309	3.535	0.0101559
'B' . Subj. Within Groups	177.809	86	2.068		

TABLE 16

ANALYSIS OF VARIANCE FOR SHOULDER DIPS

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	4604.625	45			
'A' Main Effects	158.398	2	79.199	0.766	0.4709254
Subjects Within Groups	4443.562	43	103.339		
Within Subjects	1097.375	92			
'B' Main Effects	302.972	2	151.486	19.185	0.0000008
'A*B' Interaction	120.519	4	30.130	3.816	0.0066552
'B' . Subj. within Groups	679.063	86	7.896		

TABLE 17

ANALYSIS OF VARIANCE FOR VITAL CAPACITY

SOURCE OF VARIATION	SS	DF	MS	F	P
Between Subjects	157601.000	45			
'A' Main Effects	4217.551	2	2108.775	0.591	0.5582623
Subjects within Groups	153457.000	43	3568.767		
Within Subjects	5877.000	92			
'B' Main Effects	597.447	2	298.723	5.069	0.0082965
'A*B' Interaction	199.149	4	49.787	0.845	0.5005919
'B' . Subj. within Groups	5068.000	86	58.930		

APPENDIX B

NEWMAN-KEULS COMPARISON TEST

FOR TIME EFFECT

<u>LEGEND FOR TABLES IN APPENDIX B</u>

T_1 - Trial 1 (Preseason)

T_2 - Trial 2 (Midseason)

T_3 - Trial 3 (Postseason)

TABLE 18

Newman-Keuls Mean Comparison Test for Time Effect in PWC_{170}

Time		T_1	T_2	T_3
Means		1300	1430	1460
	1	-	130**	160**
	2		-	30

p = .05 93.1468; 111.9078*
p = .01 123.7569; 139.8848**

TABLE 19

Newman-Keuls Mean Comparison Test for Time Effect in MVO_2 (lit/min)

Time		T_1	T_2	T_3
Means		3.703	4.079	4.163
	1	-	.376**	.46**
	2		-	.084

p = .05 0.2583; 0.3103*
p = .01 0.3432; 0.3879**

TABLE 20

Newman-Keuls Mean Comparison Test for Time Effect in MVO_2 (ml/kg/min)

Time	T_1	T_2	T_3
Means	49.13	54.65	55.60
1	-	5.52**	6.47**
2		-	0.95

p = .05 3.3138; 3.9813*
p = .01 4.4028; 3.9813**

TABLE 21

Newman-Keuls Mean Comparison Test for Time Effect in Arm Strength

Time	T_1	T_2	T_3
Means	795.7	870.8	945.1
1	-	75.1*	149.4**
2		-	74.3*

p = .05 70.0957; 84.2139
p = .01 93.1307; 105.2674

TABLE 22

Newman-Keuls Mean Comparison Test for Time Effect in Strength Index

Time		T_1	T_2	T_3
Means		2717	2849	2969
	1	-	91	211*
	2		-	120

p = .05 144.9530; 174.1485*
p = .01 192.5877; 217.6856**

TABLE 23

Newman-Keuls Mean Comparison Test for Time Effect in Back Strength

Time		T_1	T_2	T_3
Means		386.0	408.0	413.0
	1	-	220*	270*
	2		-	50*

p = .05 28.9412; 34.7703*
p = .01 38.4519; 43.4629**

TABLE 24

Newman-Keuls Mean Comparison Test for Time Effect in Leg Strength

Time		T_1	T_2	T_3
Means		1001	1031	1071
	1	-	30	70
	2		-	40

p = .05 90.5764; 108.8197*
p = .01 120.3418; 136.0246**

TABLE 25

Newman-Keuls Mean Comparison Test for Time Effect in Left Grip

Time		T_2	T_3	T_1
Means		121.2	121.8	124.7
	1	-	.6	3.5
	2		-	2.9

p = .05 4.889652565; 5.8744*
p = .01 6.496499521; 7.3431**

TABLE 26

Newman-Keuls Mean Comparison Test for Time Effect in Right Grip

Time		T_2	T_3	T_1
Means		124.0	125.1	128.2
	1	-	1.1	4.2
	2		-	3.1

p = .05   4.7118;   5.6608*
p = .01   6.2602;   7.0160**

TABLE 27

Newman-Keuls Mean Comparison Test for Time Effect in Chin Ups

Time		T_1	T_2	T_3
Means		10.24	10.78	12.17
	1	-	.54	1.93**
	2		-	13.9*

p = .05   1.05;   1.26*
p = .01   1.40;   1.58**

TABLE 28

Newman-Keuls Mean Comparison Test for Time Effect in Shoulder Dips

Time	T_1	T_2	T_3
Means	20.33	22.47	23.94
1	-	2.14*	3.61**
2		-	1.47

p = .05 2.053; 2.467*
p = .01 2.728; 3.084**

TABLE 29

Newman-Keuls Mean Comparison for Time Effect in Vital Capacity

Time	T_1	T_3	T_2
Means	290.5	294.2	295.4
1	-	3.7	4.9
2		-	1.2

p = .05 5.609; 6.739*
p = .01 7.453; 8.424**

APPENDIX C

NEWMAN-KEULS COMPARISON TEST

FOR GROUP EFFECT

<u>LEGEND FOR TABLES IN APPENDIX C</u>

C - Control Group

H - Non Weight-Trained Hockey Group

W - Weight-Trained Hockey Group

TABLE 30

Newman-Keuls Mean Comparison Test for Group Effect in PWC_{170}

Group		C	W	H
Means		1230	1460	1490
	1	-	230	260
	2		-	30

p = .05 243.3752; 292.7311*
p = .01 325.0676; 371.8706**

TABLE 31

Newman-Keuls Mean Comparison Test for Group Effect in MVO_2

Group		C	W	H
Means		3.534	4.162	4.249
	1	-	.628	.715
	2		-	.087

p = .05 .6677; .8031*
p = .01 .8918; 1.0202**

TABLE 32

Newman-Keuls Mean Comparison Test for Group Effect in MVO_2 (ml/kg/min)

Group		C	H	W
Means		47.91	55.70	55.76
	1	-	5.52**	6.47**
	2		-	0.95

p = .05 6.6784; 8.0328*
p = .01 8.9201; 10.2044**

TABLE 33

Newman-Keuls Mean Comparison Test for Group Effect in Arm Strength

Group		C	W	H
Means		785.3	907.9	918.4
	1	-	122.6	133.1
	2		-	10.5

p = .05 237.7877; 286.0104*
p = .01 317.6045; 363.3330**

TABLE 34

Newman-Keuls Mean Comparison Test for Group Effect in Strength Index

Group		C	W	H
Means		2777	2825	2933
	1	-	48	156
	2		-	108

p = .05 431.5840; 519.1081*
p = .01 576.4514; 659.4484**

TABLE 35

Newman-Keuls Mean Comparison Test for Group Effect in Back Strength

Group		W	H	C
Means		394.5	399.8	412.8
	1	-	5.3	18.3
	2		-	13.0

p = .05 67.6575; 81.3783*
p = .01 90.3677; 103.3783**

TABLE 36

Newman-Keuls Mean Comparison Test for Group Effect in Leg Strength

Group		W	C	H
Means		987	1038	1078
	1	-	51	91
	2		-	40

p = .05 238.9396; 287.3959*
p = .01 319.1432; 387.3959**

TABLE 37

Newman-Keuls Mean Comparison Test for Group Effect in Left Grip

Group		C	H	W
Means		119.4	122.9	125.5
	1	-	3.5	6.1
	2		-	2.6

p = .05 15.5919; 18.7439*
p = .01 20.8255; 23.8239**

TABLE 38

Newman-Keuls Mean Comparison Test for Group Effect in Right Grip

Group		H	C	W
Means		122.9	124.4	130.1
	1	-	1.5	7.2
	2		-	5.7

p = .05 16.6830; 20.0663*
p = .01 22.2829; 25.4912**

TABLE 39

Newman-Keuls Mean Comparison Test for Group Effect in Chin-Ups

Group		C	H	W
Means		10.16	11.21	11.81
	1	-	1.05	1.65
	2		-	.60

p = .05 4.2509; 5.1129*
p = .01 5.6777; 6.4952**

TABLE 40

Newman-Keuls Mean Comparison Test for Group Effect in Shoulder Dips

Group		C	H	W
Means		20.82	22.50	23.41
	1	-	1.68	2.59
	2		-	.91

p = .05 7.4281; 8.9345*
p = .01 9.9215; 11.3500**

TABLE 41

Newman-Keuls Mean Comparison Test for Group Effect in Vital Capacity

Group		W	C	H
Means		285.9	295.0	299.2
	1	-	9.1	13.3
	2		-	4.2

p = .05 43.6524; 52.5050*
p = .01 58.3050; 66.6997**

APPENDIX D

NEWMAN-KEULS COMPARISON TEST

FOR INTERACTION EFFECT

LEGEND FOR TABLES IN APPENDIX D

C - Control Group; Trial 1

H_2 - Non Weight-Trained Hockey Group; Trial 2

W_3 - Weight-Trained Hockey Group; Trial 3

TABLE 42

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN PWC_{170}

Group		C_1	C_2	C_3	H_1	W_1	W_3	W_2	H_2	H_3
Mean		1200	1214	1278	1339	1354	1505	1526	1552	1585
	1	-	14	78	139*	154*	305**	326**	1352**	385**
	2		-	64	125*	140*	291**	312**	338**	371**
	3			-	61	76	227**	248**	274**	307**
	4				-	15	166**	187**	213**	246**
	5					-	151**	172**	198**	231**
	6						-	21	47	80
	7							-	26	59
	8								-	33

p = .05 92.1; 110.7; 121.8; 129.6; 135.4; 140.3; 144.6; 148.1
p = .01 122.4; 139.3; 149.4; 156.9; 162.5; 167.0; 170.9; 174.5

TABLE 43

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN MVO_2 (lit/min)

Group	C_1	C_2	C_3	H_1	W_1	W_3	W_2	H_2	H_3
	3.431	3.479	3.691	3.821	3.858	4.285	4.344	4.413	4.512
1	-	.048	.26	.39*	.427*	.854**	.913**	.982**	1.018**
2		-	.212	.342*	.379*	.806**	.865**	.934**	1.033**
3			-	.130	.167	.594**	.653**	.722**	.821**
4				-	.037	.464**	.523**	.592**	.691**
5					-	.427**	.486**	.555*	.654*
6						-	.059	.128	.227
7							-	.069	.168
8								-	.099

p = .05 0.255; 0.307; 0.337; 0.359; 0.375; 0.389; 0.401; 0.411
p = .01 0.339; 0.386; 0.414; 0.435; 0.450; 0.463; 0.474; 0.484

TABLE 44

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN MVO_2 (ml/kg/min)

Group		C_1	C_2	H_1	C_3	W_1	W_3	H_2	W_2	H_3
Mean		46.14	47.43	49.67	50.12	51.53	57.37	58.12	58.39	59.32
	1	-	1.24	3.48	3.93	5.34*	11.18**	11.93**	12.20**	13.13**
	2		-	2.24	2.69	4.10	9.94**	10.69**	10.96**	11.89**
	3			-	.45	1.86	7.70**	8.45**	8.72**	9.65**
	4				-	1.41	7.25**	8.00**	8.27**	9.20**
	5					-	5.84**	6.59**	6.86**	7.79**
	6						-	.75	1.02	1.95
	7							-	.27	1.20
	8								-	.93

p = .05 3.27; 3.93; 4.33; 4.61; 4.82; 4.99; 5.14; 5.27
p = .01 4.35; 4.95; 5.31; 5.58; 5.78; 5.94; 6.08; 6.21

TABLE 45

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN ARM STRENGTH

Group	C_1	W_1	C_2	C_3	H_1	W_2	H_2	H_3	W_3
Mean	740.9	794.5	795.8	819.1	851.7	883.3	933.3	970.3	1046
1	-	53.6	54.9	78.2	110.8*	142 4**	192.4**	229.4**	305.1**
2		-	1.3	24.6	57.2	88.8	138.8**	175.8**	251.5**
3			-	23.3	55.9	87.5	137.5**	174.5**	250.2**
4				-	32.6	64.2	114.2**	151.2**	226.9**
5					-	31.6	81.6	118.6**	194.3**
6						-	50	87*	162.7**
7							-	37	112.7**
8								-	75.7*

$p = .05$ 79.3; 83.3; 91.6; 97.5; 101.9; 105.6; 108.8; 111.5
$p = .01$ 92.1;104.9;112.4;118.1; 122.3; 125.7; 128.6; 131.3

TABLE 46

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN STRENGTH INDEX

Group	W_1	C_1	W_2	C_2	H_1	C_3	H_3	H_2	W_3
Mean	2622	2696	2758	2797	2833	2838	2974	2992	3095
1	-	74	136	175	211*	216*	352**	370**	473**
2		-	62	101	137	142	278**	296**	399**
3			-	39	75	80	216*	234*	337**
4				-	36	41	177	195	298**
5					-	5	141	159	262**
6						-	136	154	257**
7							-	18	121
8								-	103

$p = .05$ 143.4; 172.3; 189.5; 201.7; 210.8; 218.4; 225.0; 230.6
$p = .01$ 190.5; 216.9; 232.6; 244.2; 252.9; 260.0; 266.0; 271.6

TABLE 47

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION IN BACK STRENGTH

Group		W_1	H_1	H_3	W_2	C_1	C_2	H_2	W_3	C_3
Mean		365.3	390	395	397	402.8	412.8	414.3	421.3	422.8
	1	-	24.7	29.7	31.7	37.5	47.5*	49*	56**	57.5**
	2		-	5	7	12.8	22.8	24.3	31.3	32.8
	3			-	2	7.8	17.8	19.3	26.3	27.8
	4				-	5.8	15.8	17.3	24.3	25.8
	5					-	10	11.5	18.5	20
	6						-	1.5	8.5	10
	7							-	7	8.5
	8								-	1.5

p = .05 28.6; 34.4; 37.8; 40.2; 42.0; 43.6; 44.9; 46.0
p = .01 38.0; 43.3; 46.4; 48.7; 50.4; 51.9; 53.1; 54.2

TABLE 48

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN LEG STRENGTH

Group		W_1	W_2	C_1	C_2	C_3	H_1	H_3	W_3	H_2
Mean		921.7	952	1017	1038	1060	1065	1066	1087	1104
	1	-	30.3	95.3	116.3	138.3*	143.3*	144.3*	165.3**	182.3**
	2		-	65	86	108	113	114	135*	152*
	3			-	21	43	48	49	70	87
	4				-	22	27	28	49	66
	5					-	5	6	27	44
	6						-	1	22	39
	7							-	21	38
	8								-	17

p = .05   89.6; 107.6; 118.4; 126.0; 131.7; 134.5; 140.6; 144.1
p = .01   119.0; 135.5; 145.3; 152.6; 158.0; 162.4; 166.2; 169.7

TABLE 49

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN LEFT GRIP

Group		C_3	C_1	H_2	C_2	H_3	W_2	W_3	H_1	W_1
Mean		118.1	119.6	120.1	120.4	122.1	123.1	125.3	126.6	128
	1	-	1.5	2.0	2.3	4.0	5.0	7.2	8.5*	9.9*
	2		-	.5	.8	2.5	3.5	5.7	7.0	8.4*
	3			-	0.3	2.0	3.0	5.2	6.5	7.9*
	4				-	1.7	2.7	4.9	6.2	7.6*
	5					-	1.0	3.2	4.5	5.9
	6						-	2.2	3.5	4.9
	7							-	1.3	2.7
	8								-	1.4

$p = .05$ 4.83; 5.81; 6.39; 6.80; 7.11; 7.36; 7.59; 7.77
$p = .01$ 6.42; 7.31; 7.84; 8.24; 8.53; 8.77; 8.97; 9.19

TABLE 50

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN RIGHT GRIP

Group		H_3	H_2	C_1	C_2	C_3	W_2	H_1	W_3	W_1
Mean		120.3	120.3	124.1	124.5	124.7	127.3	128	130.4	132.5
	1	-	0	3.8	4.2	4.4	7.0*	7.7*	10.1**	12.1**
	2		-	3.8	4.2	4.4	7.0*	7.7*	10.1**	12.2**
	3			-	.4	.6	3.2	3.9	6.3	8.4*
	4				-	.2	2.8	3.5	5.9	8.0*
	5					-	2.6	3.3	5.7	7.8*
	6						-	.7	3.1	5.2
	7							-	2.4	4.5
	8								-	2.1

$p = .05$ 4.66; 5.60; 6.16; 6.55; 6.85; 7.10; 7.31; 7.49
$p = .01$ 6.19; 7.05; 7.56; 7.94; 8.22; 8.45; 8.64; 8.83

TABLE 51

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN CHIN UPS

Group		C_1	C_2	W_1	H_2	C_3	H_1	W_2	H_3	W_3
Mean		9.812	10.09	10.23	11.57	10.59	10.67	11.67	12.40	13.53
	1	-	.278	.418	.758	.778	.858	1.858*	2.588**	3.718**
	2		-	.14	.48	.50	.58	1.58*	2.31**	3.44**
	3			-	.34	.36	.44	1.44	2.17**	3.30**
	4				-	.02	.10	1.10	1.83**	2.96**
	5					-	.08	1.08	1.81**	2.94**
	6						-	1.00	1.73**	2.86**
	7							-	.73	1.86**
	8								-	1.13*

p = .05 1.03; 1.24; 1.37; 1.46; 1.52; 1.58; 1.63; 1.67
p = .01 1.38; 1.57; 1.68; 1.77; 1.83; 1.88; 1.92; 1.96

TABLE 52

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN SHOULDER DIPS

Group		C_1	H_1	W_1	C_2	C_3	W_2	H_3	H_2	W_3
Mean		19.28	20.77	20.93	21.37	21.81	22.40	23.10	23.63	26.90
	1	-	1.49	1.65	2.09	2.53	3.12*	3.82**	4.35**	7.62**
	2		-	.16	.60	1.04	1.63	2.33	2.86	6.13**
	3			-	.44	.88	1.47	2.17	2.7	5.97**
	4				-	.44	1.03	1.73	2.26	5.53**
	5					-	.59	1.29	1.82	5.09**
	6						-	.7	1.23	4.50**
	7							-	.53	3.80**
	8								-	3.27**

$p = .05$ 2.03; 2.44; 2.68; 2.85; 2.98; 3.09; 3.18; 3.26
$p = .01$ 2.69; 3.07; 3.29; 3.46; 3.58; 3.68; 3.79; 3.84

TABLE 53

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN VITAL CAPACITY

Group		W_1	W_2	W_3	C_1	C_3	H_1	C_2	H_2	H_3
Mean		282.8	287.3	287.7	290.9	295	297.9	299.1	299.8	300
	1	-	4.2	4.0	8.1*	12.2**	15.1**	16.3**	17**	17.2**
	2		-	.4	3.6	7.7*	10.6**	11.8**	12.5**	12.7**
	3			-	3.2	7.3*	10.2**	11.4*	12.1**	12.3**
	4				-	4.1	7.0*	8.2*	8.9*	9.1*
	5					-	2.9	4.1	4.8	5
	6						-	1.2	1.9	2.1
	7							-	.7	0.9
	8								-	0.2

p = .05 5.55; 6.66; 7.33; 7.80; 8.15; 8.45; 8.70; 8.92
p = .01 7.37; 8.39; 9.00; 9.45; 9.78;10.06;10.29;10.51

APPENDIX E

TABLE OF MEANS

TABLE 54

MEANS FOR PWC_{170}

	T_1	T_2	T_3	Group Means
Control Group	1200	1214	1287	1230
Hockey Group	1339	1552	1585	1490
Weight Group	1354	1526	1505	1460
Trial Means	1300	1430	1460	

TABLE 55

MEANS FOR MVO_2 (liters/min)

	T	T	T	Group Means
Control Group	3.43	3.48	3.69	353
Hockey Group	3.82	4.41	4.51	424
Weight Group	3.86	4.34	4.29	416
Trial Means	3.70	4.07	4.16	

TABLE 56

MEANS FOR MVO_2 (ml/kg/min)

	T_1	T_2	T_3	Group Means
Control Group	46.19	47.43	50.12	47.91
Hockey Group	49.67	58.12	59.32	55.70
Weight Group	51.53	58.39	57.37	55.76
Trial Means	49.13	54.65	55.60	

TABLE 57

MEANS FOR ARM STRENGTH

	T_1	T_2	T_3	Group Means
Control Group	740.9	795.8	819.1	785.3
Hockey Group	851.7	933.3	970.3	918.4
Weight Group	794.5	883.3	104.6	907.9
Trial Means	795.7	870.8	945.1	

TABLE 58

MEANS FOR STRENGTH INDEX

	T_1	T_2	T_3	Group Means
Control Group	2606	2797	2838	2777
Hockey Group	2833	2992	2974	2933
Weight Group	2622	2758	3095	2825
Trial Means	2717	2849	2969	

TABLE 59

MEANS FOR BACK STRENGTH

	T_1	T_2	T_3	Group Means
Control Group	402.8	412.8	422.8	412.8
Hockey Group	390.0	414.3	395.0	399.8
Weight Group	365.3	397.0	421.3	394.5
Trial Means	386.0	408.0	413.0	

TABLE 60

MEANS FOR LEG STRENGTH

	T_1	T_2	T_3	Group Means
Control Group	1017	1038	1060	1038
Hockey Group	1065	1104	1066	1078
Weight Group	9217	9520	1087	987
Trial Means	1001	1031	1071	

TABLE 61

MEANS FOR LEFT GRIP STRENGTH

	T_1	T_2	T_3	Group Means
Control Group	119.6	120.4	118.1	119.4
Hockey Group	126.6	120.1	122.1	122.9
Weight Group	128.0	123.1	125.3	125.5
Trial Means	124.7	121.2	121.8	

TABLE 62

MEANS FOR RIGHT GRIP STRENGTH

	T_1	T_2	T_3	Group Means
Control Group	124.1	124.5	124.7	124.4
Hockey Group	128.0	120.3	120.3	122.9
Weight Group	132.5	127.3	130.4	130.1
Trial Means	128.2	124.0	125.1	

TABLE 63

MEANS FOR CHIN UPS

	T_1	T_2	T_3	Group Means
Control Group	9.81	10.09	10.59	10.16
Hockey Group	10.67	10.57	12.40	11.21
Weight Group	10.23	11.67	13.53	11.81
Trial Means	10.24	10.78	12.17	

TABLE 64

MEANS FOR SHOULDER DIPS

	T_1	T_2	T_3	Group Means
Control Group	19.28	21.37	21.81	20.82
Hockey Group	20.77	23.63	23.10	22.50
Weight Group	20.93	22.40	26.90	23.41
Trial Means	20.33	22.47	23.94	

TABLE 65

MEANS FOR VITAL CAPACITY

	T_1	T_2	T_3	Group Means
Control Group	290.9	299.1	295.0	295.0
Hockey Group	297.9	299.8	300.0	299.2
Weight Group	282.8	287.3	287.7	285.9
Trial Means	290.5	295.4	294.2	

APPENDIX F

PERFORMANCE - FITNESS CORRELATION MATRIXES

TABLE 66

FITNESS - PERFORMANCE CORRELATION MATRIX - Junior Team

Variable	PWC_{170}	MVO_2 (lit/min)	MVO_2 (ml/kg/min)	Arm Strength Index	Strength Index	Body Weight	Performance Score
	1	2	3	4	5	6	7
1	-	0.998*	0.776*	0.189	0.562*	0.666*	0.203
2		-	0.760	0.179	0.575*	0.683*	0.204
3			-	0.256	0.355	0.098	0.024
4				-	0.727*	0.006	0.218
5					-	0.472	0.238
6						-	0.109
7							-

p = .05 .514

TABLE 67

FITNESS - PERFORMANCE CORRELATION MATRIX - Senior Team

Variable	PWC_{170}	MVO_2 (lit/min)	MVO_2 (ml/kg/min)	Arm Strength	Strength Index	Body Weight	Performance Score
	1	2	3	4	5	6	7
1	-	0.806*	0.725*	0.349	0.464	0.496	0.132
2		-	0.902*	0.271	0.226	0.574*	0.047
3			-	0.233	0.104	0.168	0.226
4				-	0.345	0.125	0.143
5					-	0.316	0.006
6						-	0.552*
7							-

p = .05 0.532